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Heating · Piping and Air Conditioning

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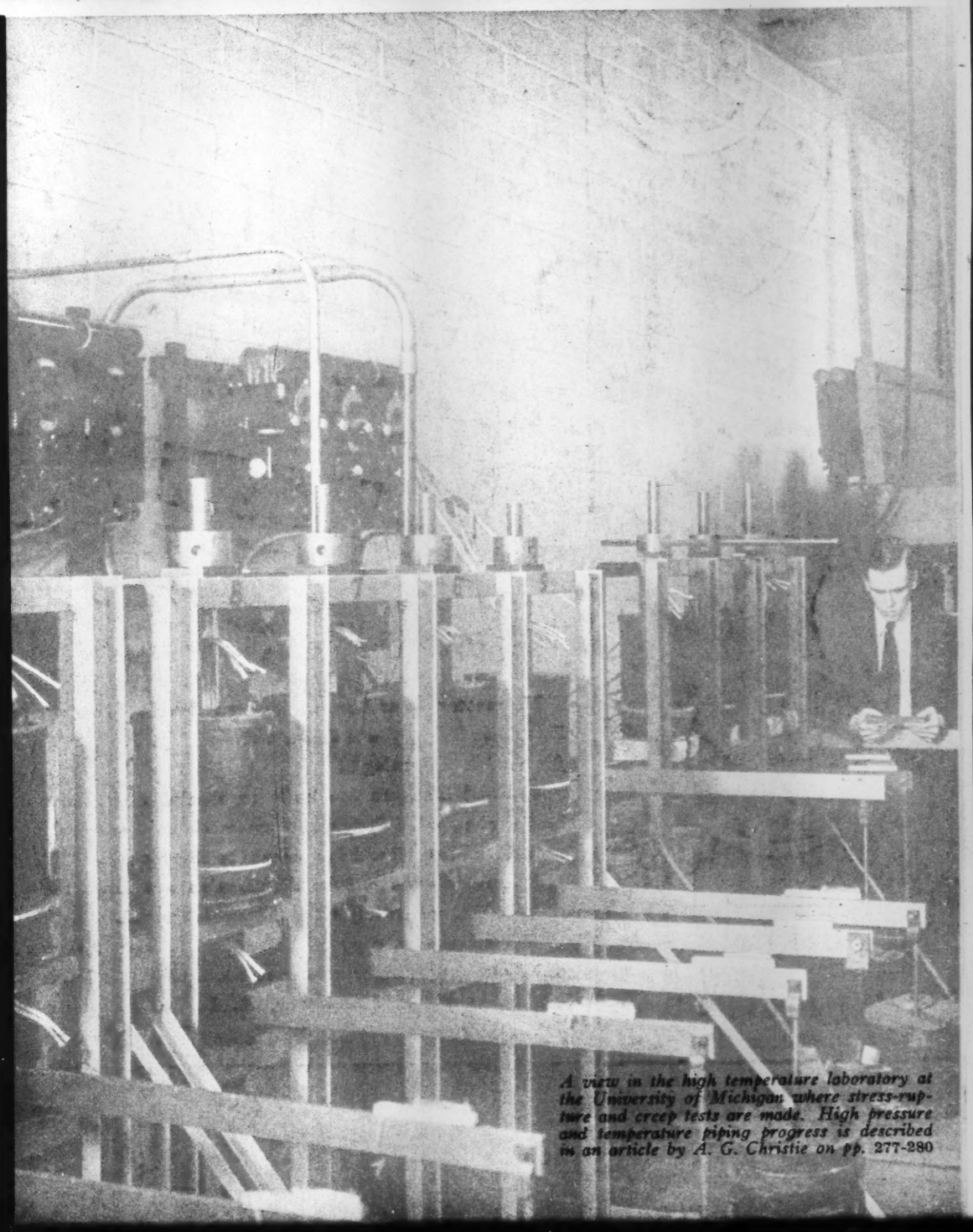

A view in the high temperature laboratory at the University of Michigan where stress-rupture and creep tests are made. High pressure and temperature piping progress is described in an article by A. G. Christie on pp. 277-280

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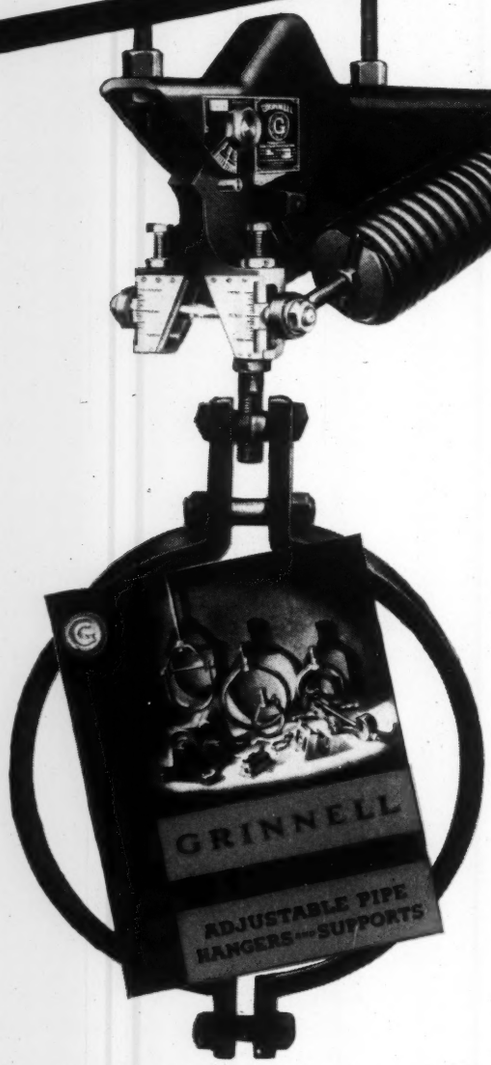

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WHENEVER **PIPING** IS INVOLVED

The Editor's Page

■ **Members of** the Heating, Piping and Air Conditioning Contractors National Association and their guests are to meet at the Drake, Chicago, May 31 through June 2, for their 50th annual convention and 50th anniversary of the organization of the national association. . . . George H. Dickerson, president of the association, in commenting on the choice of Chicago for this meeting, points out that it was a logical selection since the association was incorporated by Chicago master fitters April 12, 1889, and the first convention was held at the Hotel Leland in Chicago in September of that year. . . . The 50th anniversary meeting is an open convention and all those interested in the heating, piping and air conditioning industry are welcome, Mr. Dickerson emphasizes. Pipe welding is among the subjects to be discussed and the association's committee on welding has prepared the first of its standard procedures, which will be explained. The committee hopes that by adoption of standard procedures a method can be devised for the interchange of welders without requalification of them. The committee on standards is to report on the publication of the third edition of the HPACCNA Engineering Standards, the first edition of which appeared in 1923.

■ **Installation** of engineered air conditioning systems by local contractors was named by Dr. Willis H. Carrier, at the recent annual stockholders meeting of Carrier Corp., as the "most significant trend in the air conditioning industry" during 1938, and was hailed by him as a "healthy sign" for the industry. . . . J. I. Lyle, president of Carrier, predicts a 25 per cent increase in sales this year for the entire air conditioning industry in comparison with the 1938 sales record. He said that his company's business has been running well ahead of last year with heavy commercial units and central station installations in the lead. . . . Orders received in the first quarter of 1939 are the second highest in the history of Trane Co., according to Reuben N. Trane, president. In the three months ended March 31, orders received totalled $1,226,156 as compared with $826,824 in the first quarter of 1938. . . . Central plant air conditioning systems sold in Chicago in March showed a 35 per cent increase in total capacity over those reported in the same month last year, according to Commonwealth Edison Co. The figure was 26 installations with an aggregate rating of 798 hp, compared with 33 systems totaling 591 hp in March '38. A slight gain in sales of air conditioning capacity was also registered in the first quarter of this year; 51 central plant systems totaling 1296 hp were contracted for, compared with 56 jobs rated at 1192 hp for the corresponding 1938 period.

■ **The National Association** of Fan Manufacturers elected H. Mathis president at its annual meeting last month, C. T. Morse vice-president, and L. O. Monroe secretary-treasurer. The association has been in continuous operation for 22 years, has sponsored the standard test code for centrifugal and axial fans, certified ratings, standard methods for centrifugal fans and blowers, and basic ratings for dehumidifying type air washers.

■ **Albert J. Nesbitt,** president of the Industrial Unit Heater Association, recently announced the following committee chairmen appointments for the ensuing year: Engineering committee, E. R. Walker; finance committee, A. G. Dixon; membership committee, M. F. May; publicity committee, T. Brown; trade relations committee, J. F. G. Miller for the eastern division and J. M. Frank for the western division.

■ **Psychrometric Tables** — Tables of the psychrometric properties of air for various barometric pressures over a range from 22 to 32 in. of mercury have been compiled by William Goodman, and publication is to start in next month's HEATING, PIPING AND AIR CONDITIONING. . . . With a few exceptions, the tables are arranged and used in the same manner as those for normal barometric pressure which appeared in our January, 1938, issue.

■ **Fifteen engineers** from various sections of the bituminous coal industry met in Pittsburgh recently to chart a research program "designed to restore large tonnages of coal to the annual production of the industry." The program of technical investigations and service outlined at the close of the meeting includes the development of methods and equipment for (1) the completely automatic heating of buildings and residences with a wide range of coals, (2) ceramic and metallurgical heating and melting with pulverized coals, (3) the complete gasification of coal, (4) a coal dust engine, (5) collection and handling of ash without detrimental slagging, clinkering or discharge into the atmosphere, and (6) a system of coördination of coal research throughout the country.

■ **Announcement** of the Sixth International Heating and Ventilating Exposition to be held in Lakeside Hall, Cleveland, next January resulted in more than half of the available exhibit space being engaged by 184 exhibitors, according to the International Exposition Co., manager of the show. Previous expositions have been held in Philadelphia in 1930, Cleveland in 1932, New York in 1934, Chicago in 1936 and New York in 1938. There was a total of 327 exhibitors at the last exposition and a registered attendance of 40,057.

■ **Modifications** in the methods of publishing ASTM standard specifications and tests are to become effective in November. The major change is to combine the Book of Standards, which is issued triennially, and the Book of Tentative Standards, issued annually. The new method will be to issue the standards and tentative standards collectively in one triennial publication, divided into three parts, the first on metals, the second on non-metallic materials—constructional, and the third on non-metallic materials—general. Further details may be had from ASTM headquarters, 260 S. Broad St., Philadelphia.

■ **Comfort Cooling** Builds You Up is the slogan used in an extensive newspaper advertising campaign of the American Blower Corp. to begin this month. While the tremendous summer comfort possibilities by means of fresh air moved in great volume through homes, apartments and places of business are still not known to many, the growth of business in this field indicates a wide acceptance of this way of eliminating discomfort in hot weather, according to Ralph B. Stowell, advertising manager.

■ **Corrosion**—A number of technical societies and other organizations engaged in the study of corrosion have formed the American coördinating committee on corrosion, which is to serve as a clearing house and coördinating agency for information on experience and work in progress.

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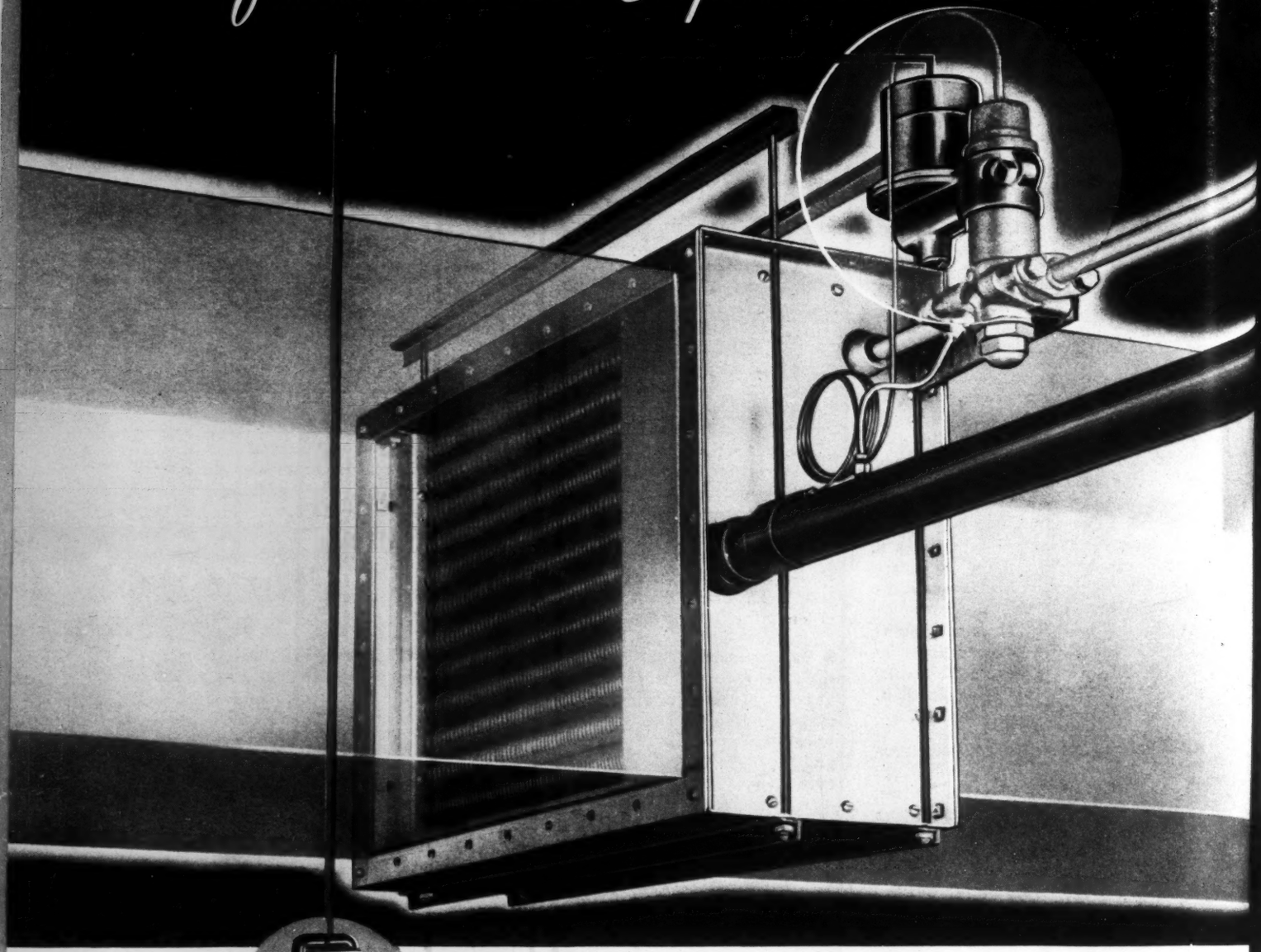

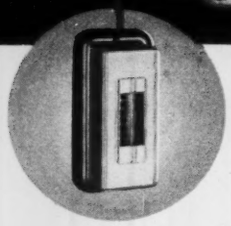

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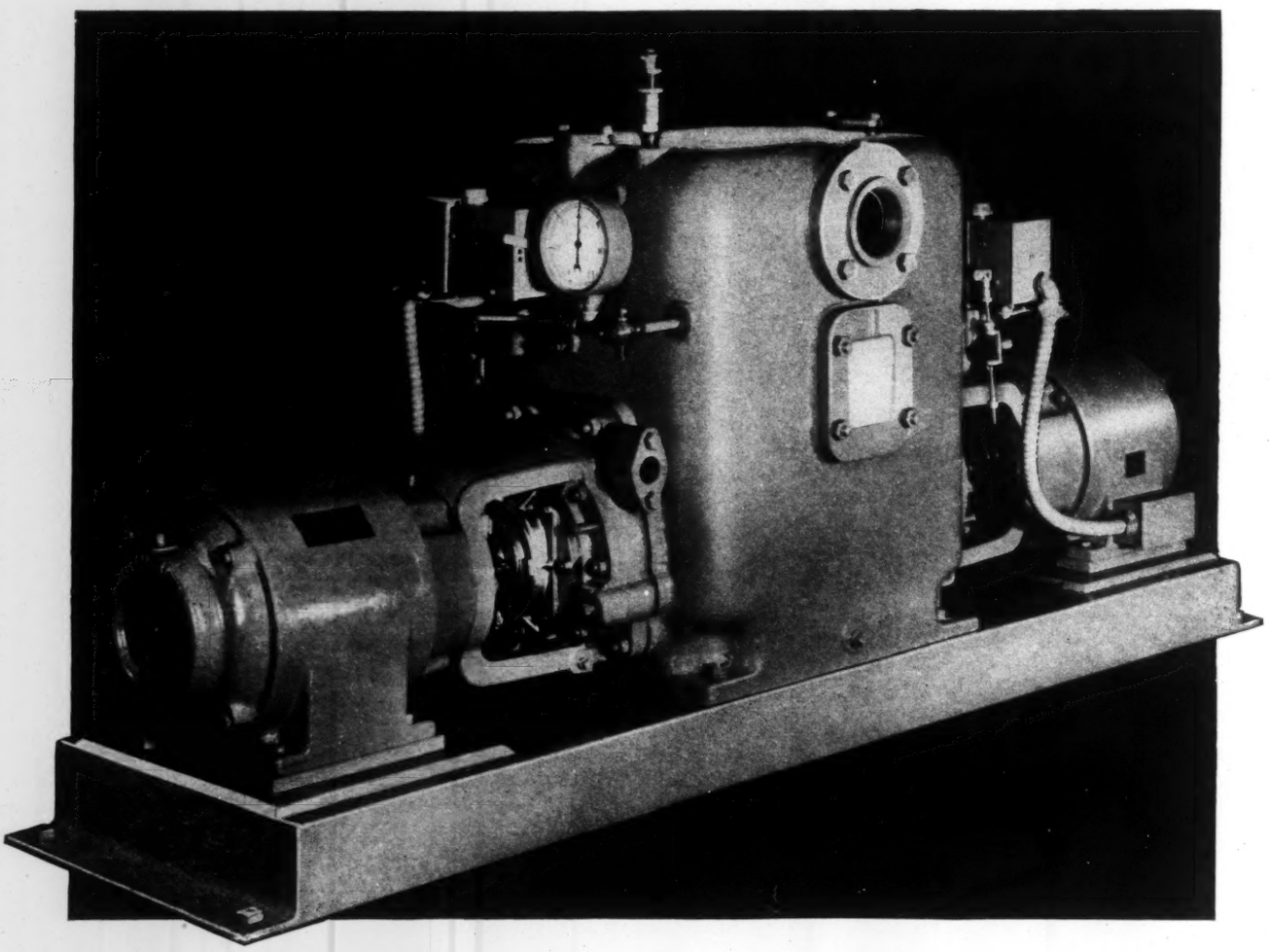

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Heating · Piping and Air Conditioning

Vol. 11, No. 5 • May, 1939

High Pressure and Temperature Piping Progress During the Past Ten Years

By A. G. Christie*

Ten years ago, Professor Christie discussed piping for high pressures and temperatures in an article that appeared in the May, 1929, HEATING, PIPING AND AIR CONDITIONING. At that time he pointed out in his concluding remarks that steam temperatures would inevitably be increased when satisfactory materials for piping, superheaters, and turbines became available. . . . The trend to high pressures and high temperatures has been one of the notable developments of the past decade; as a consequence, we asked Professor Christie to review this development since the publication of his earlier article. He is well qualified to write on the subject, for it is one he has been in close touch with for many years

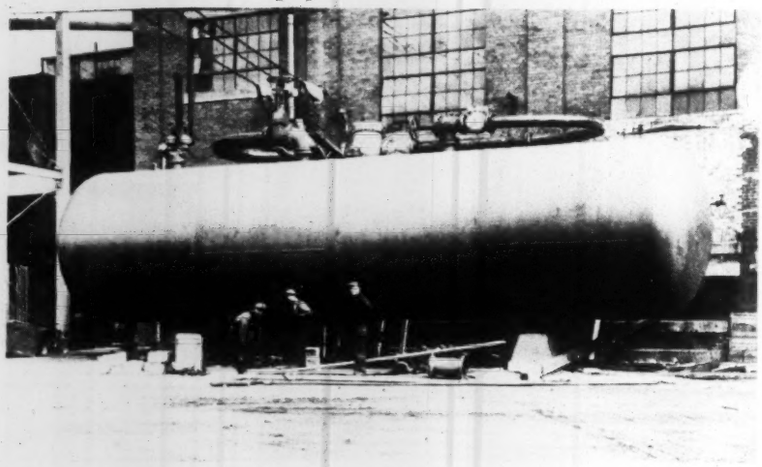
TEN years ago, the writer contributed an article on piping for high pressures and temperatures to the May, 1929, HEATING, PIPING AND AIR CONDITIONING which reviewed and discussed the state of the art at that time. The following paragraphs review certain subsequent developments of the trends discussed in the earlier article, as well as the state of the art at the present time. The earlier contribution considered such subjects as cost of high pressure plants, reheating, high pressure in industrial plants, economy of high pressures, economic limits of high pressures and temperatures, and piping for high pressures. Much of the data on economic considerations given then are of permanent value.

Valves and fittings have been standardized for pressures up to 2500 lb per sq in. Pipe wall thickness schedules have been established which with suitable selection of low alloy materials can be used for steam pressures up to 1400 lb per sq in. with temperatures up to 950 F. Boiler manufacturers and turbine builders have had considerable experience with high pressures, for many such plants have been installed during the last few years. As a consequence, high pressure equipment can readily be secured at costs comparable to those of lower pressure equipment when consideration is given to the greater service demands. Hence, the cost of the high pressure plant is not disproportionate to that of lower pressure stations for the same electrical output. The choice of pressure is therefore influenced more by such considerations as load factor, fuel cost, and whether or not the unit is for "topping" a present plant.

Reheating—Reheating was considered a necessity with high pressures in 1929 as steam temperatures were then limited to about 750 F. Since that time, it has been demonstrated at Detroit Edison Co. that a steam temperature of 1000 F can be safely employed in a commercial plant. Many recent stations have been built or are under construction without reheating. Piping from turbine to reheater and back, together with certain governing difficulties, are avoided in such plants and the expense of this additional equipment is saved. While the preceding statements cover the present trend in this country, it should be remembered that the most efficient high pressure plant in the world (the Port Washington station, near Milwaukee) is a reheating plant with initial conditions at the boiler outlet of 1320 lb per sq in. gage, 825 F, and with steam reheated at an intermediate stage to 825 F.

Steam Storage—Steam storage in accumulators appeared to offer economic advantages in this country in 1929, particularly in industrial plants subject to widely fluctuating process demands. Large numbers of steam accumulators have been installed in Great Britain and on the continent, but comparatively few are in use in this country, for the development of the large boiler and furnace capable of meeting rapid changes in demand has discounted the advantages of steam accumulators for central stations. However, certain industrial plants have experienced increasing steam demands for processes that are of a widely fluctuating nature, and under these conditions, the operation of the existing boiler plant may become unsatisfactory due to poor economy of fuel. Rather than add additional new boilers, this condition may be remedied at moderate expenditure by the installation of a steam accumulator. This accumulator takes steam at boiler pressure when the process demands are light and discharges steam later at a lower pressure to processes when sudden heavy steam-requirements occur. The load on the boiler is steadier, firing becomes more regular and fuel economy may be improved. Conditions in many of the older industrial plants may be bettered by the installation of steam storage equipment.

*Professor of Mechanical Engineering, Johns Hopkins University, and President, American Society of Mechanical Engineers.



Modern steam accumulator installation of welded construction showing unit before the application of insulation

An Outstanding Development—The adoption of high steam pressures and temperatures for both industrial power plants and central stations has been one of the outstanding developments of recent years. Pressures of 650, 850 and 1350 lb per sq in. are used in many plants. One industrial plant at Cincinnati employs 1800 lb per sq in., while a new installation in a central station at Michigan City contemplates 2400 lb per sq in. Steam temperatures which were limited 10 years ago to about 750 F have been increased in new plants to 850 F, 900 F, and in one new British station to 960 F. An installation in one of the plants of the Detroit Edison Co. operated for several years at 400 lb per sq in. and 1000 F temperature.

High pressure alone presents no serious difficulty to the piping designer or manufacturer. However, temperatures above 750 F could not be used until satisfactory pipe materials had been developed for these increased temperatures and until the art of piping construction for such conditions had been learned. Alloy steels with chromium and molybdenum added—together with other alloying elements, as titanium, columbium, or nickel—are now employed for such high temperature piping. The technique of manufacturing such piping had to be acquired and experience with its properties over extended periods of subjection to high temperatures and pressures has been necessary. Sufficient data have accumulated to assure satisfactory piping designs for the highest pressures now employed and for steam temperatures up to 1000 F. Alloy steels (such as carbon-molybdenum steels) are even used for high pressure steam piping with temperatures below 850 F.

The tubing subject to the most severe conditions in steam plant operation consists of the superheat tubes in that section of the superheater containing the hottest steam. One realizes that such tubes may be 50 F or more hotter than the steam itself as it leaves the superheater. Further increases in steam temperature would lead to recognized gains in steam station economy but can only be realized when even better heat resisting tubing is available. One must not assume that the limit has been reached; we may expect steam temperatures of the order of 1200 F or more in comparatively few years.

Creep—One of the principal difficulties with high temperatures is the tendency of steel to creep, "creep" being the indefinite and continued slow elongation of steel when subjected to high temperature and high stress. Research has demonstrated that the creep strength of a metal is much below its short-time tensile strength at the same temperatures. Since creep is continuous the designer must proportion his piping so that the rate of elongation does not exceed some fixed limit determined by experience. This rate is often expressed as a certain part of a millionth of an inch per inch per hour. For example, some steam turbine parts have creep limits of one hundred millionth of an inch per inch per hour.

Studies have been made in England and elsewhere of lead models of pipe lines, as lead creeps under stress at room temperatures and its action can readily be studied and deductions drawn for similar phenomena with steel piping at higher temperatures. These tests with lead seem to indicate that a piping system will relieve itself of excessive bending stress through creep. The resultant relaxation leaves the piping under such low stresses that further elongation is very slow. If this observation is found to hold with high temperature alloy steel piping, creep problems will assume a less serious aspect.

Another piping element subject to creep is the bolting material. This must be stressed to a certain figure to maintain a tight joint. But high stress at high temperature leads to creep and thus to a relaxation of the stress. This decreased stress slows down the rate of creep. If this relaxed stress is still sufficient to keep the joint tight, all is well, but if not, a leak results. Many special steel alloys have been developed for such bolting material.

Experiment has demonstrated that with a steel under high temperature and high stress, creep is comparatively rapid at first but under constant load soon slows down. A question at once arises regarding the action of a steel pipe under repeated or alternating loading, both with constant high temperature and with temperature removed, as, for instance, when the steam becomes saturated during shut-down periods. Some excellent experimental work along this line has been done abroad and is reported in the December, 1938, *Brown Boveri Review*. These studies indicate that there is no material difference in the elongation and contraction processes between metal pieces unloaded to room temperature or with stress removed and the steel retained under no load at 932 F. The unload pauses at 932 F show a somewhat greater elongation from creep than those at room temperature. One can conclude from these tests that the periods of time a part is under stress and free from stress during its working life and the temperature when free from stress will have an effect upon its behavior. This subject of repeated loading and unloading needs further study.

Much remains to be learned about creep, and considerable work is being done on the subject. The American Society of Mechanical Engineers has recently published a volume on creep data in which a comprehensive assembly of data is presented. R. W. Bailey submitted the results of his extended studies to the Institution of

Mechanical Engineers, November, 1935, in a paper entitled The Utilization of Creep Test Data in Engineering Design. H. W. Gillett, in an address before the American Institute of Mining and Metallurgical Engineers, has pointed out the impossibility of correlating the various data on creep supplied by different investigators and that there is not yet a proper theory to account for the various creep phenomena. It is therefore evident that piping designers must use much judgment in applying present available creep data, and continue to study results of experience and test data before reaching a final conclusion on the effects of creep.

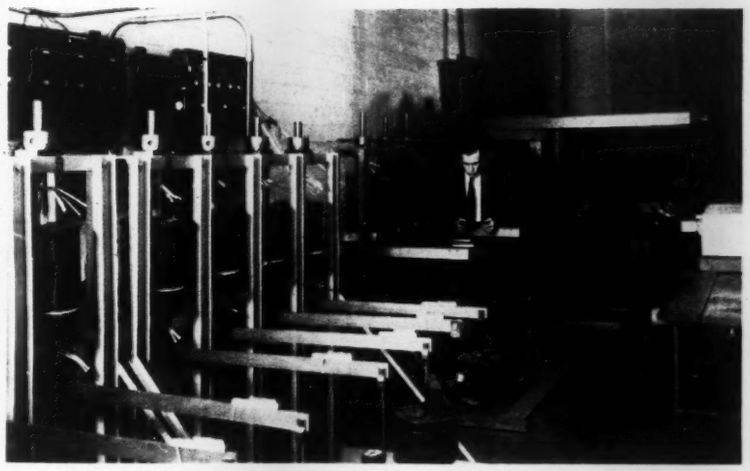
Experiences with 1000 F steam piping were discussed in detail in a recent paper before the December, 1938, ASME meeting by R. M. Van Duzer, Jr. and Arthur McCutchan.[1] They concluded that the materials of construction withstood the service conditions rather well. The authors consider that with the recent advances in knowledge of high temperature characteristics of alloys now available and the advances made in the construction of power plant equipment, the design and operation of a 1000 F plant is a practical thing if the savings to be gained are justified economically.

Corrosion—Corrosion is another factor of much importance in piping design at all temperatures. Piping has corroded rapidly at low temperatures when conveying city water or salt water solutions. The obvious remedy is to ensure thorough deaeration of this water before it enters the piping. Returns of heating systems when under vacuum may absorb oxygen through leaks which will lead to rapid corrosion. Tight valve stems and joints are essential. Hot water feed piping must also be watched for similar difficulties. In some cases an oxygen absorbing material as sodium sulphite or ferrous hydrate is added to such feed water to absorb any remaining traces of oxygen leaving the deaerator.

Corrosion may occur at high steam temperatures from dissociation of a small portion of superheated steam in contact with the hot tube surface. Tests at Purdue University were reported in a paper by A. A. Potter, H. S. Solberg and G. A. Hawkins entitled Investigation of the Oxidation of Metals by High Temperature Steam in the 1937 ASME *Transactions*.[2] The authors found that at 1200 lb per sq in. and 1000 F, steam will attack even chrome nickel stainless steel tubing with the evolution of hydrogen and the formation of a black layer of oxide inside of the pipe. They concluded that in view of this reaction it is probable that any commercially available superheater tube will be subject to a certain amount of oxidation by high pressure, high temperature steam. With very high steam temperatures, alloy materials should be used which will react with the steam to produce a thin, dense, tightly adherent layer that offers maximum resistance to the penetration of the oxidizing agent and will not crack or spall when subjected to rapid or extreme changes in temperature.

Some of the hydrogen evolved during dissociation diffuses through the metal of the tube. This raises some interesting questions. For instance, does such hydrogen penetration lead to embrittlement of the steel? Evidence is not conclusive on this point. Some experimenters feel that there is no danger of hydrogen embrittlement at temperatures now in use. Further research is needed to settle this point.

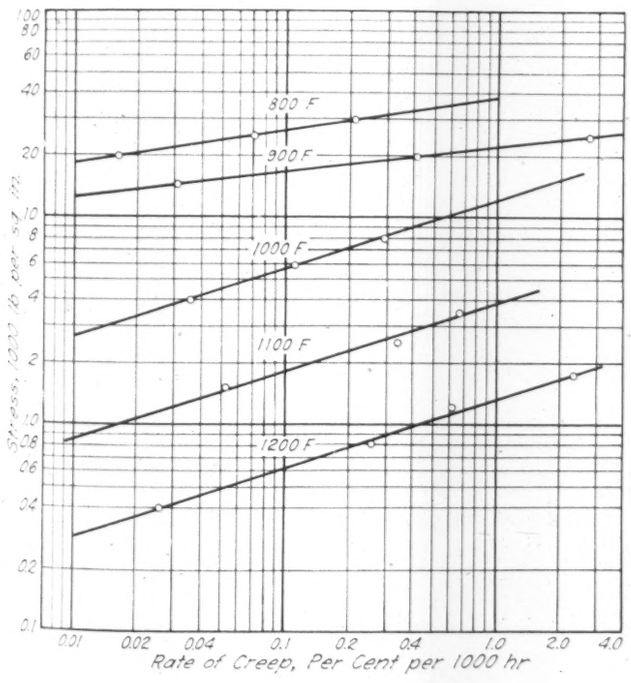
R. M. Van Duzer, Jr., and Arthur McCutchan, in their previously mentioned paper, gave valuable data upon corrosion of various steels under 1000 F steam temperatures. They concluded that the early scale layers formed inhibit subsequent attack by the steam, and that even small additions of alloying elements greatly influence the rate of corrosion. In regard to the effects of stress on corrosion, the authors believe that when con-



View of high temperature laboratory at University of Michigan showing a battery of stress-rupture units in the foreground and a battery of creep units in the background. A total of 22 creep and 22 rupture units are in operation

[1]See excerpts on pp. 163-164, Heating, Piping and Air Conditioning, March, 1939.—Ed.

Creep—stress curves at indicated temperatures for 1015 steel (electric)



[2]See abstract, pp. 247-249, Heating, Piping and Air Conditioning, April, 1938.—Ed.

servative stresses are selected for steam equipment, the additional scale resulting from stress should not be a serious factor. In the case of a stressed tube, about the same amount of scale was obtained on the outside as on the inside of the pipe. This factor of outside corrosion of steam piping at high temperatures is often given little thought by designing engineers.

Welding Piping—Ten years ago it was usual practice to employ fittings and piping with bolted flanged joints. Present practice is to weld high pressure and high temperature piping throughout. Some installations have no flange joints except at the boiler and at the turbine and these may soon be replaced by welded connections. Valves and fittings are now available with welding necks, while joints in straight pipe are welded in regular practice.

When such joints are welded in straight pipe runs, the ends of the pipe to be welded are properly beveled. A backing ring is placed inside to prevent welding icicles and beads and the joint filled with the welding metal. This requires that particular attention be given to the inside diameters of piping in order that the backing rings may fit properly or their utility is sacrificed.

The technique of welding has been greatly improved in the last few years. Satisfactory welds can be made by many operators, and in the case of electric welds the use of the arcronograph[3] aids in securing a sound weld. Standard tests have been developed for welders. Welding rods for various purposes and for various classes of pipe material are now available. Methods have also been developed for properly annealing the joint in place by means of electrical heating coils.

Research on Materials—The preceding paragraphs emphasize the great importance of metal composition in the strength and suitability of piping materials for high temperatures. Extensive and continued research is therefore necessary to determine what properties each alloy element or combination of elements may contribute to the steel. Such research by Prof. A. E. White and his associates at the University of Michigan has added many valuable contributions to our available knowledge. The work at Battelle Memorial Institute is also worthy of mention. The effects of "killing" of the steel, of grain size and of corrosion resistance are now better understood but still leave much to be explained.

Conclusion—A wealth of information on high pressure and temperature piping has been made available during the last 10 years in society papers, articles, catalogs, codes, ASTM specifications, etc. It has been possible to mention here but a few of these contributions.

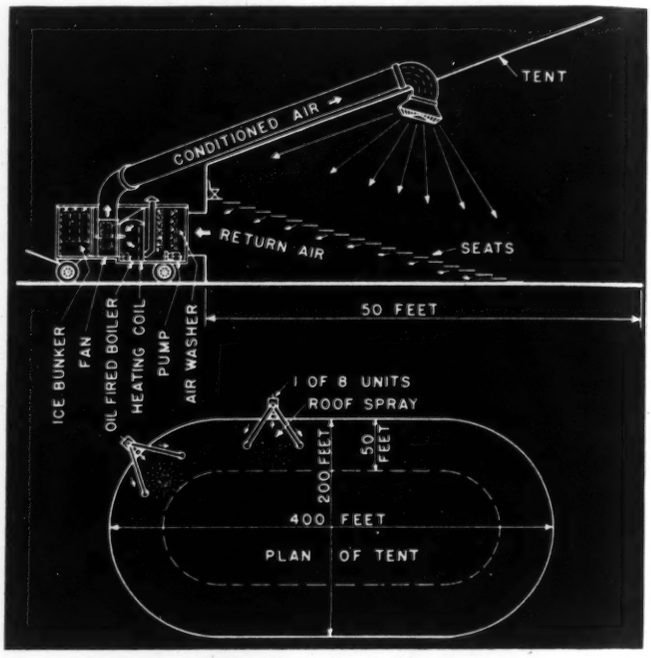
Great progress has been made in the development of piping methods and materials for high pressures and temperatures and in our knowledge of alloys and their properties for these services. Much research and development work remains to be done in order that temperature limits may be further extended. Better piping materials and fabrication methods are available today than 10 years ago. But even better materials will be at hand in the years to come.

[3]See pp. 91-93, HEATING, PIPING AND AIR CONDITIONING, February, 1939.—ED.

Photograph of high temperature laboratory at University of Michigan and creep—stress curves courtesy department of engineering research. Photograph of steam accumulator courtesy Foster Wheeler Corp.

The Circus Gets Air Conditioning

There's a new thrill in store for devotees of that great American institution—the circus. Ringling Brothers and Barnum and Bailey have closed a contract for comfort cooling for the big tent. Eight complete sets of equipment will be required, each to be mounted on a trailer truck. Through sixteen huge diffusers, cooled air will be discharged into the tent. Exhaust facilities will permit withdrawal of approximately the same amount of air, so that a constant supply of cooled air will be provided.



Arrangement for cooling the circus tent

The equipment (see sketch) carried on each of the eight large trailers consists of a fan and special air washer with ice compartments and heating coils. Two circulating pumps will spray cold water, obtained with melting of tons of ice per hour, into the washer, through which the air to be cooled will circulate. In chilly weather, an oil fired boiler will provide steam for the heating coils.

It is expected that the addition of comfort cooling will enable Ringling Brothers and Barnum and Bailey to increase the attendance at all performances throughout the year.—F. B. STUBINGER.*

*Buffalo Forge Co.

New Idea?

Unusual methods of generating electricity are used in Italy, if a recent caption under a picture in a leading metropolitan newspaper can be believed. According to the caption, natural steam obtained from wells in northern Italy is conveyed "to tanks in which the steam is condensed before being converted into electricity." The caption fails to explain the process after the steam has been successfully condensed.

Heating and Air Conditioning Engineer Reviews His Ten-Year-Old Predictions

[Samuel R. Lewis* discusses an article he contributed to the May, 1929, HEATING, PIPING AND AIR CONDITIONING, to see how his earlier predictions have been fulfilled]

IN 1929 I attempted to forecast heating, ventilating and cooling practices as I thought they might be 10 years from then. I am now 10 years older and 10 years more conservative, and I surprise myself—on rereading that old article in HEATING, PIPING AND AIR CONDITIONING—at my temerity. I am willing to discuss in 1939 some of the predictions over which my 1929 neck was exposed, but I will not now try to predict what may happen by 1949.

Types of Housing—In my 1929 article, I predicted the spectacular development of the cooperative apartment house. Due to the world depression or to something else, construction of skyscraping cooperative apartment buildings has not been what I then expected. I can believe that the difficulties in composing the psychological differences of the various tenant-owners may have some part in this.

We find today our large cities nearly all equipped with government owned "slum clearance" projects, in which neither the city nor the tenant has a proprietary interest. The buildings of these clearance projects, with central heating and modern sanitary arrangements, are more comfortable than many of those which were torn down, but apparently never can return interest and sinking fund on their cost, and will be an ugly burden on the general tax.

It is doubtful in my mind whether the cost per room or per apartment for heat and hot water with these projects does not exceed that which would provide equal service under private ownership. It is generally easier for the tenants to open a window for preventing overheating than to close a radiator supply valve, and there is little if any automatic temperature control installed or practicable for the individual apartments. This is one of the reasons why large, central steam heating systems for living quarters generally do not show up as well as they might from the fuel economy standpoint.

Fuels—The 1929 story predicted increased use of pulverized coal equipment in heating boilers. While all of the heating boilers using it in 1929 continue, as far as I can learn, to do so, and while pulverized coal is very widely used in large electric generating plants, there has been no noticeable increase in the number of smaller installations. A revival of an old intermediate combustion process has occurred, in the spreader stoker, where the coal is crushed coarsely and is blown or sprinkled above the fire bed, burning partly in suspension.

The underfeed stoker for low pressure heating boilers has been improved greatly and has been reduced in price. The low cost, acceptable efficiency, ability to burn low grade fuel without much smoke and the simplicity of the forced draft underfeed stoker has made it predominant in the coal burning field.

In 1929 I made no mention of fuel oil or fuel oil burners. They have been through almost a revolutionary development, as the heavy residual oils have steadily become cheaper. In many cases it is less costly to burn preheated mechanically atomized oil than to burn solid fuel, and there is a decided trend toward the use of oil of high viscosity.

I predicted an increase in gas burning heating systems for residences, using mechanically circulated warm air, but did not anticipate the tremendous extent to which this method would be used, or the economy and satisfaction which would attend it.

Vacuum and Hot Water Heating—My 1929 predictions concerning the uses and advantages of low temperature, high vacuum steam heating have been fulfilled and exceeded, as these plants have proved remarkably economical. I did not foresee the 1939 trend toward forced circulation hot water heating, which has the advantages of wide temperature variations to suit the outside temperature changes as well as low power cost for circulating the heat carrier and which eliminates for all practical purposes corrosion, scale and maintenance of air valves.

Piping—There has been a tremendous increase in the popularity of welding ferrous piping and in the use of sweated joints with copper piping. Round pipes continue to be employed, despite my 1929 prediction about the development of rectangular tubing and its employment in heating systems. I note, however, that rectangular tubing is being used for refrigeration piping, as described on page 710 of the November, 1938, HPAC.

Radiation—Recessed and enclosed convectors, and unit heaters, are universally used—as predicted. The *square foot*, meaning 144 sq in. of heat transmitting surface, is obsolete, and *EDR*, meaning equivalent heat transmitting surface of 240 Btu per hr, has superseded it for steam. When hot water heating is concerned the *Mb* unit, interpreted as the surface which will transmit 1000 Btu per hr, is in general use. I believe that this

"The present trend is for the installation of complete air conditioning apparatus to return to the established heating and air conditioning contractor, with his superior knowledge of local conditions and better arrangements for quick servicing."

*Consulting Mechanical Engineer. Member of Board of Consulting and Contributing Editors.

convenient unit of measurement—approaching very gently the metric system—will come into more and more popular service.[1]

My hope for a rating of heat transmitters which warm the air of rooms, based on the heat delivered by the transmitter rather than on the heat input to it, has not been realized but there are indications that it will arrive eventually.

The unit heaters of 1929 have been much improved, especially as to general beauty and to noise reduction. The circular overhead type of unit heater (not present but predicted in 1929) is performing with general satisfaction in 1939.

Insulation—Construction of a new building in 1939 without building insulation is practically unheard of, and the cost of such insulation has been reduced with an increase in efficiency. One sees few new houses without snow on the roofs in 1939, indicating that insulation is present.

Refrigeration—I had no anticipation in 1929 of the far flung results in air conditioning which would follow the development of the flourine refrigerants. My 1929 predictions concerning evaporative cooling of railway cars by water sprays definitely were soaking wet. (Ten years ago, I thought railway cars would be cooled evaporatively by spraying water over the roofs).

An interesting recent invention proposes to employ a liquid of the flourine group as the heat transporter in both summer and winter. The vapor rising from this compound, when heated by a flame as in a steam boiler, can be circulated and condensed in a heating system much as H_2O is circulated and condensed, and is pumped back to the boiler for continuous circulation. In summer the same boiler and vapor operate in an absorption system, not unlike an ammonia absorption system, to pick up heat from the recirculated air of the building. The waste heat is discarded through an evaporative condenser.

Condensing Water—Evaporative condensers, while old in the art of refrigeration, have received much attention and have been developed into very efficient and compact devices well adapted to serve with even large capacity refrigerating systems. Much attention, and attendant improvement in capacity and efficiency, is being shown to cooling towers.

It is evident that the overloading of water and sewer facilities due to wasting condensing water from air cooling systems will necessitate increasing dependence on evaporative condensers and cooling towers. The recent use of a compounded refrigerant liquid for directly cooling the motors of airplanes leads to a hint that wider use of a non-freezing, non-incrusting liquid for heat transfer purposes may be imminent, since water has many disadvantages.

Ventilation Air—The relaxing, in many engineering codes, particularly those of the American Society of Heating and Ventilating Engineers and of the city of Chicago, of the time-honored requirement for 30 cfm of outside air per person required for ventilation is significant, and apparently leads to reductions in operating and investment costs without sacrifice to health and comfort. There has been a great improvement by manufacturers of air diffusing grilles, following excellent research in their laboratories.

Control—Air conditioning designers, as a whole, have learned the necessity when cooling of means for temperature control of rooms or at most of zones, independent of the temperature for other rooms or zones at the same time. This has led to the development of various schemes for controlled reheating of the air in the individual ducts of central cooling systems, since without such reheating or its equivalent it is impossible to give adequate control of the relative humidity and since when there is any great interference with air delivery volume there will be odor and draft troubles.

Turbines—There is an awakening consciousness evident in the use of low pressure steam turbines with their reliability and freedom from lubrication in connection with the larger heating and cooling systems. This may be due to some extent to increasing familiarity by engineers with condensing equipment. Many refrigerating compressors, water circulating pumps and vacuum pumps employed in air conditioning systems are being turbine driven.

Marketing Air Conditioning—For a time the manufacturers of small air conditioning condensing and evaporating units marketed these directly to the consumer, assuming all responsibility for application design and for piping and duct installation. This scheme received some impetus due to ability for a time by the manufacturers to hire otherwise unemployed engineering salesmen. It was generally unprofitable to the manufacturer and not particularly satisfactory to the salesmen, judging by the enormous turn-over of partially trained men. The present trend is for the installation of complete air conditioning apparatus to return to the established heating and air conditioning contractor, with his superior knowledge of local conditions and better arrangements for quick servicing.

My conclusion is that the 1939 heating and air conditioning engineer, as compared with his 1929 self, has become a very much more competent person, delving into refrigeration, electricity, hydraulics and chemistry to an extent not at all anticipated 10 years ago. The interest and the romance of the profession undoubtedly will increase even more during the next decade.

"The 1939 heating and air conditioning engineer, as compared with his 1929 self, has become a very much more competent person, delving into refrigeration, electricity, hydraulics, and chemistry to an extent not at all anticipated 10 years ago. The interest and the romance of the profession undoubtedly will increase even more during the next decade."

Price reductions and wage increases have tripled the purchasing power of the American hourly factory wage in the last 25 years, according to the Machinery and Allied Products Institute, which has published its findings in a booklet entitled Machinery and the American Standard of Living.

[1] In the current edition of the ASHVE Guide, it is noted that it is the eventual plan to eliminate use of the expression "a square foot of equivalent direct radiation," replacing it with *Mb*, the equivalent of 1000 Btu, and *Mbh*, the equivalent of 1000 Btu per hr, which have been approved by the ASHVE.

Tenant Reaction to Air Conditioning

Superintendent J. W. Stiles* told about how air conditioning was announced to his tenants and what their reactions were in an address before the Southwest Building Owners and Managers recent conference from which this article has been taken

I BELIEVE building owners and managers are as much interested in "tenant reaction" to air conditioning as in almost any other phase of the subject. If we knew beforehand what the reaction of our tenants or of the renting public would be, there would be no indecision as to whether or not to undertake conditioning. If we were certain that a large majority of our tenants not only wanted air conditioning but would be willing to pay the added cost to have it, then I don't think we would hesitate but would—if at all possible—install it.

It is with this in mind that I want to relate our experiences with tenant reaction during and after the installation of air conditioning and related modernization work in our building in Houston.

Principal Features of Plant—The building has 22 stories and contains approximately 190,000 gross sq ft of space with 132,000 sq ft rentable area, including the ground or street floor. It is exposed on all sides except for a five story building joining on the south. Its principal exposures are to the north and east. The bank occupies the entire first and second floors. The other 20 floors contain 431 offices, slightly more than half of these being double units consisting of reception room and private office; the others are single offices. The interior walls are metal lath and plaster construction 2 in. thick with much of their area prism glass. Ceilings above the second floor are 10 ft 4 in. high. Prior to air conditioning and modernization, each single room was equipped with a ceiling fan with a 150 watt lighting unit and each double unit had two such fixtures. Each room had a radiator and its piping. With air conditioning, all this equipment has been removed.

The air conditioning plant consists of four 300 rpm vertical "Freon" compressors with a combined capacity of 501 tons of refrigeration, so arranged that almost any desired portion of total capacity may be utilized. Weather conditions and bank holidays often make it possible to shut down a considerable part of the equipment. Eighty-five tons, or $\frac{1}{6}$ the total capacity, is idle every bank holiday, with quite a resultant saving. Condenser water is circulated through a forced draft cooling tower on the roof. There is a fan room on each floor in space made available by re-locating the fire escape, and this room contains blower fan, conditioner, filters, outside air intake, bypass shutters, and control and recording devices.

Zoning and Duct System—Each floor is divided into four zones, according to exposure (north, east, west and interior zones) and the building is divided vertically into four floor sections or units, each unit entirely separate as far as distribution ducts are concerned from any other unit. Thus, conditioning could be discontinued at any time in any four floor section without affecting other floors. However, we do not expect to make use of this feature in order to offer large users unconditioned space at lower rates.

Distribution ducts are carried along corridor ceilings, with branches into each office through its front or corridor wall. No ducts run across an office or through partition walls from office to office. This duct plan eliminates the unsightly condition of main ducts passing through the center of a group of rooms and also prevents transmission of sounds from room to room through ducts. Corridors are utilized as return air ducts. The corridor ceilings were lowered from the original height of 10 ft 4 in. to 8 ft 2 in. to provide the necessary space above them for the main ducts. These suspended ceilings were coved, or rounded downward, to join the side walls at a height of 7 ft, or at the line of the mullion between door and transom. The transoms over the corridor doors were left in place but are not visible from the corridor side. This gives the corridor ceiling a "pullman car effect," and with the recessed or flush type lighting fixtures is an improvement over the former high ceilinged corridors.

Not a Question of Competition—The building was built in 1910 and is one of the older buildings in the city. At the time of the air conditioning installation, the building was fully occupied and is fully occupied today; there was therefore no question involved of air conditioning to attract new tenants or to hold old ones. We were not immediately faced with the competition of an air conditioned building, as there was—in 1937—no air conditioned building in Houston except the Humble Oil Co.'s home office building, entirely occupied by themselves.

We had had several inquiries by out-of-town applicants about air conditioned space and thought we could see some hand writing on the wall, as it were. The question before us, then, was simply one of keeping up with—or a little ahead of—the march of progress.

The idea and experience of air conditioning in their offices would be entirely new to our tenants, although our banking space has been air conditioned summer and winter since 1923. Naturally, in considering the advisability of this rather expensive venture, there was considerable speculation as to what the tenant reaction would be; whether they would like air conditioning or not, or whether or not they would be willing to pay the advance in rental rates that would come with it. Some other buildings, we knew, had sounded out their tenants either by personal poll or by questionnaire to get their reactions before making a decision. We were advised that at that time (early 1937) such polls were usually resulting in a vote of about 80 per cent for and 20 per cent against air conditioning.

Our management decided against going to the tenants at all for their attitude in the matter but to go ahead, let

*Superintendent, Second National Bank Building, Houston, Texas.

the contracts, and then announce the program. This was done, and though some few tenants had noticed the engineers measuring and checking through the building and had asked some questions, the announcement was a surprise to most.

Announced to Tenants—It has been truly said that anyone who expects to satisfy everybody completely the first year or so under air conditioning must be at least 50 per cent *diplomat*, 75 per cent *psychologist*, and 100 per cent *optimist*. Our management thought that the time to start with the diplomacy and the psychology was right at the beginning, so the announcement of the intention to air condition was made in a form letter sent to each tenant on May 1 stating that air conditioning would be installed throughout the building, that work would start within 30 days, and that conditioned air would be turned in on September 1. Notice was given that under air conditioning rental rates would be advanced about 20 per cent (or actually 4c per sq ft per month) but not until April 1 the next year. It was stressed that in the meantime the tenant would have had nearly a month of hot weather in which to try a "free sample" of cooling, and all winter to experience the heating under the year 'round system. This letter also announced that during this time electric meters would be installed, and that beginning April 1 a charge would be made for current used for lighting. The rate to be used in charging this current was stated, and an estimate of approximately what the cost would be for the current used by the modern indirect lighting fixtures which were to replace the fan and light combination units.

Thus, the whole picture was laid before the tenant. He was told what he could expect in the way of increased bodily comfort, through the complete modernization program of cooling, heating and lighting, but at the same time a frank statement was made of just about what this was going to cost him. The fact was particularly stressed that it would be almost a year before any charge would be made for any of these things, which gave him ample time to try out the sample and decide whether or not to like it and remain in the building, or not to like it and find a new location. There may be some difference of opinion as to whether this course was good psychology or not, but we thought that it was. Naturally, the tenant reaction was awaited with considerable interest.

Reaction to Announcement—On the whole the reaction to the air conditioning idea was favorable. The anticipated 80 per cent for and 20 per cent against ratio proved to be nearly correct, though I don't believe quite 20 per cent of our tenants registered really firm opposition. On the other hand comparatively few were enthusiastically for it, either. The great majority were open minded, and decided that as long as it did not cost anything to try it they would wait and see. That was exactly what we wanted as we felt sure we could please them if given a chance.

The fact that a charge was to be made for electricity for lighting brought forth more protest than did the idea of a 20 per cent rent increase for air conditioning. Our tenants had been enjoying (and many wasting) free electric current for years, and seemed to think on their divine right to continue to do so. The fact that a superior type of lighting was to be furnished them didn't take much of the sting out of it, and even now after nearly a year of paying for their current, there is still some grumbling.

There was no more than the usual amount of moving. Everybody sat tight and showed the finest spirit of coöperation with the contractor's forces and the building management throughout the progress of the installation work which, though carried on principally at night, still created some discomfort and inconvenience. A few tenants asked that their space be passed over or skipped, as they did not care for conditioning and did not want to be disturbed. It was explained to them that this could not be done because all steam radiators and piping were to be removed and unless ducts were installed their space would be unheated in winter. Of course, that settled that question. My observation was that these objectors seemed toward the last to be the most anxious to see the work finished and to experience the cooler temperatures.

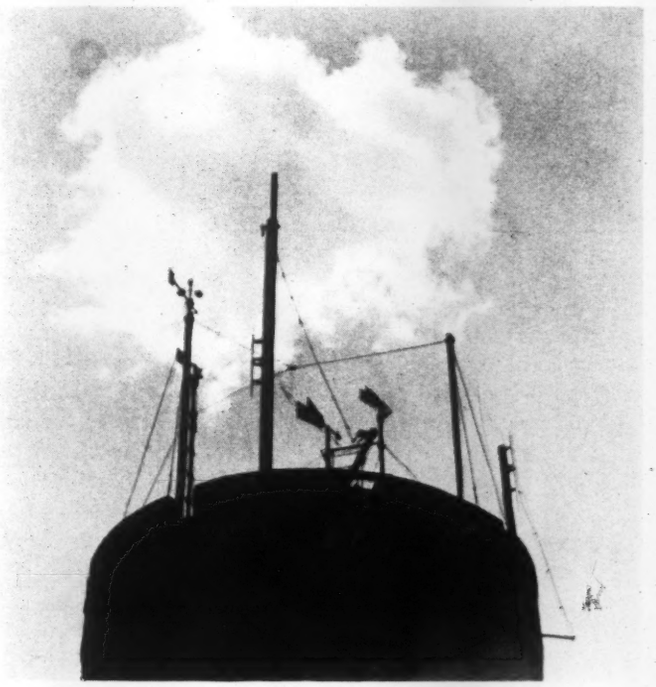
Air Conditioning Sells Itself—Whether it was the power of suggestion or just real old hot weather that caused the following incident, I am not psychologist enough to say, but one man who declared at first that he would never have air conditioning in his offices moved his residence to an air conditioned hotel as soon as the first one to be conditioned was ready for operation before the summer was over, and even before our plant was in operation. Another tenant, who was very opposed to air conditioning "just on general principles" went through most of the first summer with all conditioned air blocked off from his rooms by his special request so that he could keep his windows open. You can imagine our surprise when he asked to have his conditioning restored. I asked him why the change of heart after such a long period of opposition, and he said "I have just returned from a two weeks vacation in Colorado, and I cannot stand the heat." Since then his offices are serviced for year 'round air conditioning and he is enthusiastic about it.

I mention these two incidents to show that air conditioning will sell itself to tenants even though they may be prejudiced against it in the beginning. I believe that they prove also the good psychology of our plan to give tenants a free sample before making a charge for something that they knew nothing about. In the month or so prior to the April 1 deadline when the advanced rates were to go into effect, some half-dozen small vacancies occurred. This was somewhat more than the normal movement but only one of the number would admit that air conditioning or higher rates prompted his move. The others gave other good and logical reasons for moving. The space thus made available was immediately taken by others perfectly willing to pay the price for air conditioning, and numerous applications from tenants in unconditioned buildings were turned down because of lack of available space.

[*Concluded on p. 287*]

Long-Range Weather Forecasting

Its Present Status and Future Possibilities



By I. I. Schell*

The possibilities of forecasting next winter's or next summer's weather are of considerable interest to heating and air conditioning executives and engineers. Were we able to say, within reasonably accurate limits, that the coming summer would be particularly severe, for instance, it would undoubtedly have a definite effect on plans for summer air conditioning, production schedules, engineering and promotional effort. . . . Because weather is an important factor in heating and air conditioning work, and long-range forecasting of it offers interesting possibilities, the editors asked Mr. Schell to discuss its status. He was formerly associated with the Department of Agriculture in a survey of long-range forecasting methods; recently, he returned from an eight-month stay in Europe where he was engaged in study and research on the subject

THE difficulties of long-range weather forecasting are not in general adequately recognized. The complexity of the problem and lack of sufficient data have prevented—so far—its solution on an adequate scale, with the result that only occasional successes in long-range forecasting have been possible. Yet the "demand" for long-range forecasts has been so great that a "supply" has been forthcoming before its quality would bear even the most cursory examination. The range of magic and pseudo-science invoked by man through the ages to give him a clue to the future weather has been extraordinary.

The skepticism about the possibility of eventually being able to make long-range forecasts has, happily, not been shared by all. The British government in India began to encourage long-range weather research in the 1880's. In Russia, an institute for long-range forecasting was established in 1912 and in Germany such an organization was created in 1929. In some other countries work along these lines bore either a semi-official or private character, and it appears that the problem about which a scientist-poet wrote nearly 200 years ago

> "What greater privilege could to mortal man given be
> Than the ability the weather changes to foresee"

is being slowly solved in the countries where most attention and encouragement has been given to it.

Basis for Long-Range Forecasts—Meteorology is a physical science, and yet relatively speaking it is still in its infancy. A season that is exceedingly dry or wet, cold or warm, has an abnormal physical factor (not the stars or the moon) at work. Often a very dry summer month is followed by another dry month and a very cold winter spell almost immediately afterward by another cold spell. It is this persistence when it is preceded by abnormal features of the weather in other large regions of the globe that seems to hold the greatest promise or reliability in seasonal forecasting. However, weather extremes brought about in this way are infrequent and hence only occasional seasonal forecasts could be made with fair reliability. Relationships between the seasonal weather in some large regions of the world with the following season's weather of other regions imply a time-difference and hence if reliably established would provide a basis for long-range forecasting.

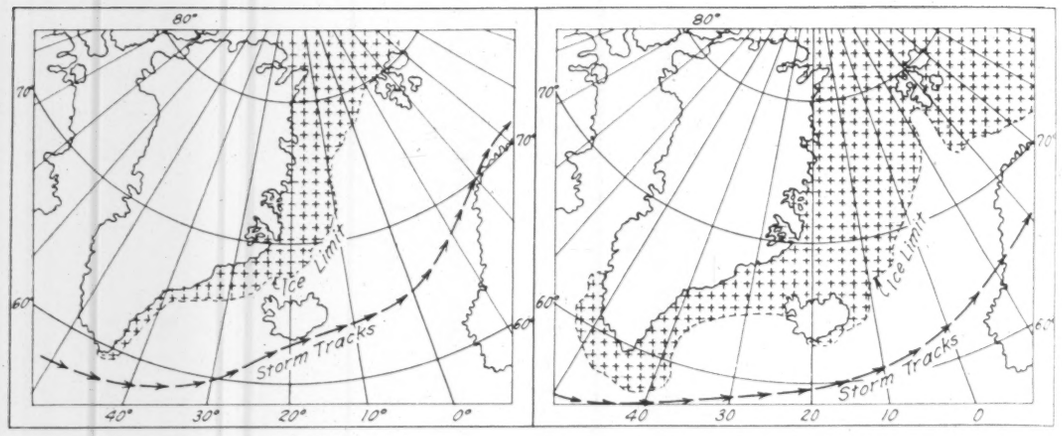
A simple way of representing a relationship between two series of data is by means of a *correlation coefficient*. The technical phrase means that if we have two series of numbers the variations of which are connected, there will be a certain proportion of the variations of each which are associated with those of the other, and this proportion is called the correlation coefficient between the series. If it is nearly unity, the numbers vary closely together; If it is small, there is little relationship between them; and if it approaches —1 the relationship is again close but the series are inversely related.

Oscillations and Relationships Between Seasonal Weather—The process of determining the desired time-lag relationship involves first the discovery of regions over which the weather variations are linked. Such variations are known as *fluctuations* or *oscillations* and were first visualized by the Swedish meteorologist Hildebrandsson. After their existence was confirmed by the British Lockyers (father and son) they were given vital shape and their usefulness established by Sir Gilbert Walker, whose efforts figured largely in improving

*Research Fellow, Blue Hill Meteorological Observatory, Harvard University.

the method of forecasting the rain-bearing monsoon of India.

The next step is to discover regions whose weather variations are related to the preceding meteorological variations of other regions, and the foundation for this—a foundation pregnant with great possibilities—was laid by Walker. The largest known system of related seasonal weather is that called the *southern oscillation*. This system in the southern summer (December to February) has a correlation coefficient of over 0.7 with the monsoon rainfall of India and the Nile flood, and in the southern winter (June to August) a correlation coefficient of over 0.6 with the subsequent winter temperature of large areas of North and South America. From this it follows that we have sometimes the means of forecasting three months in advance—at any rate approximately, for the relationships indicated so far are not very close. However, the methods of prediction can be improved by the study of the relationships of individual areas.



Light Ice Conditions
Storm tracks farther north

Heavy Ice Conditions
Storm tracks farther south

Difference Between Actual and Forecast Weather—Since a real control of 0.7 by previous conditions is about as good as is now available for forecasting, the difference between the actual and the forecasted weather will be considerable. It is only when the derived indications are markedly favorable or unfavorable that they are of significance. The issuance of a forecast only when the deduced indications are extreme, and consequent silence when conditions appear roughly normal, may be likened to the following analogy: "In a race with 30 starters a conspicuously good horse may, without undue risk, be backed to come in within the foremost six, and we may feel confident that a thoroughly bad animal will be in the last six; but it would be unwise to hazard much on the likelihood that a commonplace individual will finish among the central six." It may also be said that it is quite unlikely that the first six to place would come from the group of the poorest horses or that the last to finish would be the best six animals. Predictions can therefore be issued occasionally.

Other Bases for Long-Range Forecasts—Approaches to long-range forecasting tried in Russia and Germany were a little different. For the indications of the coming seasonal weather the meteorologists studied the behaviour of the past weather in Europe and in the surrounding regions from a series of specially prepared maps. Another approach tried in Russia and Great Britain involves conditions in polar regions. These have long been held significant for the weather in lower latitudes. When the polar ice cap attains an abnormal growth and an excessive amount of broken up ice and cold water which results from melting come down to the warmer ocean in the following spring and early summer, then the zone of interaction between the cold polar and warm sub-tropical waters which favors storminess is gradually displaced toward the equator and the path of the subsequently developing storms is also displaced. At present the state of polar ice forms the basis of an experimental method of seasonal forecasting in Great Britain and in Russia.

Results Achieved—In practice the following results have been obtained. The earliest regular seasonal forecasts were those of the Indian rain-bearing monsoon of June to September started over half a century ago, in 1885. They have been issued every time the indications were sufficiently definite. These forecasts have been right about seven out of 10 times. In southern Rhodesia, where the methods developed in India were adopted in 1922 and where large departures in rainfall occur frequently, eight forecasts were issued over an 11 year period and seven of the eight were correct.

In Australia severe droughts have long made long-range forecasts particularly desirable and led to the development of methods based on cycles or fixed periods. These cycles broke down so frequently that their use was discarded.

In the United States considerable attention to seasonal forecasting has been paid for several decades by H. H. Clayton of Canton, Mass., at one time meteorologist at the Blue Hill observatory, later, head of the forecasting division of the Argentine weather service, and now engaged in private research and practice. On the west coast, G. F. McEwen of the Scripps institution of oceanography succeeded at first in developing a method of forecasting based mainly on a short series of ocean temperatures. Realization of the difficulties did not discourage him and he is making an energetic attempt to overcome them. A far sighted secretary of agriculture several years ago ordered a survey of the existing methods of long-range forecasting and called in a group of men to advise on a program leading to the development of such a method.

At the Blue Hill observatory the foundation laid mainly by the British and Russian scientists was somewhat broadened and moderate progress in experimental seasonal forecasting has been made. For example, for the state of Montana during the last 13 years, markedly favorable or unfavorable indications of the coming winter precipitation could have been derived for the years 1925-26, 1928-29 and 1930-31. Two of the three fore-

casts would have been right, including the prediction for the winter of 1930-31 when the precipitation amounted to only 40 per cent of its normal value. If more caution were exercised only one prediction would have been issued, that of the last-named winter. This result would have limited the predictions to only one in 13 years and therefore may appear to be of small value; but it is better to recognize the limitations and issue a forecast only when that can be done with reasonable safety than to give predictions when they are no better than mere guesses. It is relevant that in none of the remaining 12 years was the departure in the winter precipitation large, say more than about 20 per cent, and the absence of markedly favorable or unfavorable indications was in itself a correct indication that no extreme departures would arise.

Of the other countries where practical results were achieved, Germany and Russia should be mentioned. In the former, F. Baur published during the past few years several seasonal forecasts which were correct. In Russia, Multanovski and Wiese, using two different methods, attained some success in winter and spring forecasting.

Summarizing, "occasional" long-range forecasting has come to stay. There will be times when advance indications of abnormal seasonal weather will be so definite that a forecast can be issued with considerable reliability. The results so far have been achieved through years of patient research and as more research is encouraged, still better results should follow.

Tenant Reaction—

[*Concluded from p.* 284]

That is the story of the acceptance of air conditioning in our building; we think it a very good record. We feel that an overwhelming majority of our tenants are now sold on air conditioning, have accustomed themselves to the new rates, and are not likely to vacate. Our tenants are not under lease and can move on 30 days notice. We do know, however, that the number of applicants for space, especially those from out of town, who demand conditioned space, is increasing. A recent case of this kind was rather amusing. An insurance firm was sending a new agent down from the home office in Connecticut to take charge of the Houston office, and insisted that he move the local office into an air conditioned building for fear he might not survive his first Texas summer unless so protected.

I have questioned some of the managers of offices where a number of workers are employed as to what effect air conditioning has had on worker efficiency. They all agree there is an improvement, but often give different features the credit. Most seem to agree, however, that the elimination of street noises due to closed windows is one of the greatest aids to worker efficiency. Interruptions and distractions are reduced, and the lower noise level quiets the nerves and makes for better tempers toward the end of the day, and thus better efficiency.

Our experience has indicated that in Houston a year 'round temperature of 78 F is correct, and this is what we attempt to maintain at all times with 45 to 50 per cent relative humidity. Our installation does not have individual room control where the tenant can regulate the temperature himself. We give them all the same temperature. Whether this method is best or not is a debatable question. I think each method has its advantages and disadvantages.

Here to Stay—Most office buildings now being planned or built are putting in air conditioning as standard equipment. These newer buildings with conditioning installed during construction have two decided advantages over the older building which air conditions after some years of occupancy. Their first advantage is the lower cost of installation, and the second is the possibility of obtaining a more finished, better looking final result, due to duct work being better concealed.

I do not know any way for the older building to overcome the cost advantage, but I want to emphasize the fact that, because of the appearance advantage, it is most important that anyone planning the air conditioning of an existing building should give most careful thought to the layout of the duct distribution system so that the very best possible appearance may be obtained and unsightliness avoided.

Office building air conditioning, I believe, is here to stay and will be demanded of all first-class buildings.

Power Conference Discusses Air Pollution

The problem of reducing air pollution by power plants was discussed by Dr. R. V. Kleinschmidt at the Midwest Power Conference, held at the Palmer House, Chicago, April 5-7.

"Ever since man first used fire," began Dr. Kleinschmidt, "he has faced the problem of air pollution by products of combustion. From building his fire in the open air to leeward of his camp, he progressed to a smoke hole in his tent, and finally to a chimney. This epoch-making device has dominated the field for a thousand years, and is still by far the most universal means of handling the smoke and fume problem. Within the past 25 years, however, engineers have turned considerable attention to the study of flue gases."

It is the impurities—smoke, partially burned or decomposed combustible material, solids in the forms of cinders and fly ash, and certain acid gases of which the major one is sulphur dioxide—and not the major constituents of the flue gases which are the objectionable materials. The major constituents are nitrogen, carbon dioxide, and water vapor, which are normal and valuable constituents of the atmosphere. Because of the very small size of the solid particles from powdered coal burning boilers, the problem of removing them is very complicated and the particles hang in the air for many hours. Mixtures of acid gaseous impurities, very corrosive in the presence of moisture, complicate the matter of cleaning flue gases still further.

Dr. Kleinschmidt described the development of and results achieved with a wet type collector. In discussing research on the problem, he stated that in trapping fine dust particles with a water spray, the water particles must be very small. His work has indicated that if the diameter of the dust particle is less than about 1/200 of the diameter of the water particle, the amount of dust caught drops off very rapidly.

Installation of Compressed Air Equipment Covered in New Code

By Dan L. Royer*

THE formal adoption of the Safety Code for Compressed Air Machinery and Equipment by the American Standards Association is of importance to all persons and organizations who install compressed air equipment.[1] While the code has been drawn up in the simplest form possible to facilitate its adoption by cities and states that may wish to regulate compressed air equipment, it also will prove a valuable reference in connection with the installation of compressed air equipment in political jurisdictions where no regulations have been adopted or are contemplated. An effort was made to get the coöperation of all organizations interested in the construction, installation and operation of compressed air equipment to participate in the formulation of the code, with the result that the organizations that participated are representative of American industry. It is hoped that when the code has been applied in industry that it will be revised and amplified through the suggestion of the persons and organizations who have occasion to use it.

The new ASA Safety Code for Compressed Air Machinery and Equipment recommends safe practices in installing, maintaining and operating such equipment. It has been designed for use by concerns manufacturing or using compressed air machinery and equipment, and as a guide for state authorities in formulating safety rules and regulations. . . . The chairman of the committee responsible for the development of the code discusses provisions of it which relate to installation

Compressors—Section 4, compressors, is of particular importance when selecting and installing new compressors or relocating compressors already in service. The protective devices required are considered the minimum. While the contractor who installs a compressed air system usually is not interested in its operation and maintenance it is desirable that he should be familiar with the requirements in rule 4.4 on lubrication, and 4.6 on operation and maintenance. An endeavor has been made in these rules to eliminate the conditions that cause explosions in piping systems and receivers from the ignition of vaporized oil by high temperatures.

Cooling—Rule 4.5, cooling, is important in this connection as the failure of the cooling water supply in water cooled compressors should be guarded against because of the possibility of damage to compressor cylinders and pistons and the danger of excessively high air temperatures.

Section 5, aftercoolers, merely requires that aftercoolers be designed to carry safely the maximum pressures contemplated. It was considered impractical to require aftercoolers on all systems, for obvious reasons, but an effort was made in the notes under this heading to point out the desirability of aftercoolers. It is believed that the installation of properly designed aftercoolers would do a great deal in preventing system and receiver explosions by preventing air temperatures of sufficient intensity to cause the ignition of oil vapors. The use of aftercoolers also permits the removal of condensation which is necessary in preventing water hammer in the system.

Piping—Section 6, which applies to piping, is of particular interest to the readers of HEATING, PIPING AND AIR CONDITIONING. It should be noted that this section, in addition to other requirements and suggestions, refers to the American Standard Code for Pressure Piping (ASA B31.1-1935). Section 2 of the pressure piping code applies to gas and air piping systems and contains all of the requirements that are to be applied to compressed air piping systems.

Valves—Rule 6.5, which applies to valves that may be used in compressed air piping systems, is of importance. Paragraph A requires one or more spring loaded safety valves between the compressor and any stop valve that may be installed in the compressor discharge line and the air receiver. These valves should have capacity sufficient to limit the pressure in the discharge line to not more than 10 per cent above the receiver pressure. While stop valves in this line are not recommended and should be avoided, it is not always possible to eliminate them. Unless relief of sufficient capacity is provided for this line, it is possible that an operator might carelessly start a compressor when a stop valve is closed, with disastrous results to the discharge line, the compressor, or both.

Paragraph B of rule 6.5, valves, discourages the use of globe valves in any portion of the air discharge piping because valves of this type may cause trouble by trapping oil and condensation and may cause difficulty because of the derangement of discs due to pulsation in the system. It should be remembered that when globe valves are used they should be installed so that they close against pressure.

Receivers—The requirements of the ASME Code for Unfired Pressure Vessels have been adopted for air receivers. While this requirement automatically prohibits the use of hot water tanks as air receivers, the compressed air code carries a specific note, "Household hot water tanks should not be used as air receivers," to emphasize this requirement. The installation of vessels not designed for air receiver service has been responsible for many serious accidents. While these vessels often

*Chief Engineer, Ocean Accident and Guarantee Corp., Ltd. Chairman, American Standards Association Sectional Committee on Compressed Air Equipment and Machinery.

[1]Copies of the new Safety Code for Compressed Air Machinery and Equipment (B19-1939) are available from the American Standards Association, 29 W. 39th St., New York, N. Y., for 30c each.

have the theoretical strength to withstand the pressures to which they are subjected, their construction is such that in air receiver service they may fail. This is particularly true of kitchen tanks that have relatively flat areas adjacent to seams and heads that are improperly designed or installed. Receivers with these construction faults frequently pulsate or "breathe" when subjected to air receiver service, particularly if the source of compressed air is a single cylinder compressor. This pulsation may result in crystallization and ultimate failure.

The provision in rule 7.2, installation, is worthy of careful attention. In installing receivers, proper clearance to permit inspection should always be provided. When this requirement is met, receivers are situated so that none of their surfaces are exposed to dampness and contact with earth or concrete. This tends to eliminate external corrosion that results from improper installation in addition to providing access for inspection and maintenance.

Gages and Valves — Rule 7.4, gages and valves, requires that every air receiver be provided with one or more spring loaded safety valves and that no valve of any type be placed between the receiver and the safety valve or valves that protect it. Sufficient safety valve capacity to prevent the maximum allowable pressure on the receiver being exceeded by more than 10 per cent is required. The lack of safety valve protection on air receivers is a common cause for receiver failures. Even though a receiver is of adequate strength and properly designed for the working pressure to which it is subjected, if proper relief protection is not provided by safety valves a derangement of control apparatus may cause the compressor to subject it to pressures so great that violent explosion results.

Too frequently it is believed that a compressor may not have capacity or the driving motor sufficient power to subject a receiver to dangerous pressures. A number of instances have been encountered where the persons installing the equipment believed that the possibility of overpressure was eliminated because the driving belt might run off of its pulleys or slip when the pressure rose to a dangerous point. There should be no question about the necessity for protecting receivers against overpressure with safety valves of adequate capacity in addition to any automatic control devices that may be provided. Safety valves must be installed to provide a second line of defense against overpressure should these devices fail.

Only those portions of the code of particular interest to those concerned with installing compressed air equipment have been described here. The other sections are of importance particularly to those responsible for the operation and maintenance of compressed air machinery and equipment.

The committee that developed the Safety Code for Compressed Air Machinery and Equipment will welcome suggestions for revisions and additions to it.

American Standard for Steel Pipe Flanges and Flanged Fittings (B16e-1939)

The Manufacturers Standardization Society of the Valve and Fittings Industry has established October 1, 1939, as the effective date for applying these standards to new production. The important changes from the 1932 edition of the standard are as follows:

1) The title of the standard has been changed to "Steel Pipe Flanges and Flanged Fittings."

2) The larger sizes of the 1500 lb standard, 14 to 24 in., inclusive, which were proposed but not approved in the 1932 edition of B16e have now been approved as standard. Detailed standard dimensions have also been included for pipe flanges and fittings for use at 2500 lb steam pressure.

3) There were a number of changes made in the 1500 lb standard in the height of hub for screwed and lapped flanges, as well as adding the ½ in. and ¾ in. sizes. On the 900 lb standard, screwed flanges were added so as to include all sizes. This also occurred in the 600 lb screwed flanges and the 400 lb screwed flanges. Also smaller sizes were added to the 300 lb standard and ½ and ¾ in. sizes were included in the 150 lb flanges.

4) Detailed dimensions for welding neck flanges have been included for all pressures, 150 to 2500 lb, inclusive. A recommended practice for the details of welding bevel is also included.

5) Pressure-temperature ratings for flanges and fittings made of carbon-molybdenum and equivalent alloy steels have been added.

6) Detailed dimensions for ring joint facings and ring numbers have been incorporated in the standard which are identical with those given in API Standard No. 5-G-3-1937. Pressure-temperature rating tables for flanges and fittings equipped with ring joint facings have been added also for both carbon and alloy steels.

7) The section in the introductory notes dealing with marking has been revised to make it conform with MSS Standard Practice No. SP-25.

8) Physical and chemical properties for carbon-molybdenum alloy steel in accordance with ASTM Specification A 157-36, Grade C 1 as modified in accordance with the ASTM 1938 *Proceedings*, have been added and physical and chemical properties for steel forgings for flanges in accordance with ASTM A 181-37, A 105-36, and A 182-36, Grade F 1 have been brought up to date. Chemical requirements and Brinell hardness for carbon steel nut material in accordance with ASTM A 194-38T have also been included.

9) Tables showing length of alloy steel bolt studs for the different pressure standards with various kinds of flange facings have been added.

10) A figure illustrating the method of designating location of tapped holes for drains has been added.

11) The thickness of flange, minimum, dimensions for 150 lb loose flanges, sizes 3½ in. and smaller, have been made slightly heavier than formerly. The flanges on the fittings, however, which are reinforced by being cast integral with the body of the fitting, have been left unchanged.

12) Due to extensive amplification of the introductory notes, as well as the footnotes of certain of the tables and the addition of new material, an index has been added, covering certain important items of the standard.

Copies of this standard may be had from the American Society of Mechanical Engineers, 29 W. 39th St., New York, N. Y., for $1.25.

Methods of Establishing *k* Values

How Heat Conductivities Have Been Determined

By Kalman Steiner* and Sydney D. Black†

MODERN handbooks, textbooks, and other sources make technical information easily available to anyone concerned with problems involving heat flow. Few except research workers take the time to investigate the sources of these data, for the engineer is concerned principally with the solution of problems and not with historical anecdotes. There is, however, a fascinating story back of the rather prosaic looking tables of conductivity values that are the tools of the heating, piping or air conditioning engineer. It is a story having its beginning earlier than most of us might at first suspect.

Conductivity values have of course been established for the three states of matter: solid, liquid and gaseous. The actual laboratory experiments were always made with simple geometric forms, for the mathematical derivations of the equations are complex and would lead to insoluble integrations if other shapes of conductors were involved. These forms will be considered in the following order: rods, hollow cylinders, plates, spheres, prisms.

Use of Rods—One of the earliest conductivity experiments was that of J. Ingen-Hausz in 1789. He based it upon comparison of a known conductivity with one that was being sought, and thereby established a simple ratio. Several rods of identical dimensions but different materials were coated with the same thicknesses of wax and mounted with one end of each rod in a heater maintained at a constant temperature, Fig. 1. After a period of time, the distance from the heater out to the point on each rod where the wax remained solid was noted. In other words, he attempted to establish points of equal temperature on each rod. Of course such a method was inaccurate; wax does not have a definite melting point; steady heat flow conditions were not attained and therefore *k*, the coefficient of heat conductivity, varied with temperature.[1] The method was considerably improved by Biot in 1816.

It remained for Despretz, in 1822, to derive the mathematical expression for heat flow under the above described conditions, from which *k* could be calculated for a solid conductor. It was necessary that Despretz know the coefficient of heat convection or transfer from the rod surface to the surrounding air, and further that he assume a constant value of *k* over the length of the rod, with temperature, and uniform temperature across any cross section. Despretz used a single rod, Fig. 2, heated at one end, and measured temperature along the rod by means of thermocouples. In developing his equation, Despretz had to assume a rod of infinite length so that the temperature at the end of the rod would equal the air temperature. In order for the finite rod used in the experiment to simulate an infinite length, it was merely necessary to conduct a calculated amount of heat away from its end. This constitutes a method for determining *k* directly from temperature measurements on a single rod, without the need for comparison to readings on a rod of known *k*.

The objections to this last method were that the coefficient of convection (transfer to air) was not always known or readily determined and that the removal of a correct percentage of heat from the end of the finite rod was difficult. To overcome the first objection, Despretz worked out a second procedure, involving two rods of different materials but identical dimensions, *k* being known for one material. Here he was able to assume the convective heat transfer to surrounding air to be the same for both rods, and so eliminated from the equation of comparison. By observing distances from the heater on the rods at which the same temperatures existed at the same moment, or observing temperatures which obtained at the same moment at equal distances from the starting point, the ratio of the conductivities of the two rods was established, which ratio gave the conductivity being sought for the other material.

To overcome the second objection, that of simulating infinite length of rod, three temperature readings can be taken along two finite rods: t_0, t_1 and t_2 at distances of 0, L, and $2L$ from the initial point, as shown in Fig. 3, and from these data the ratio of the conductivities of the two rods can be obtained. As previously, the rod

*Ace Engineering Co.
†Deparment of Physics, Armour Institute of Technology.
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[1]The coefficient of heat conductivity *k* is expressed in amount of heat transferred per unit time per unit area, and per degree per unit length. Any temperature scale may of course be used, but for a single calculation, all temperatures must be expressed in the same system.

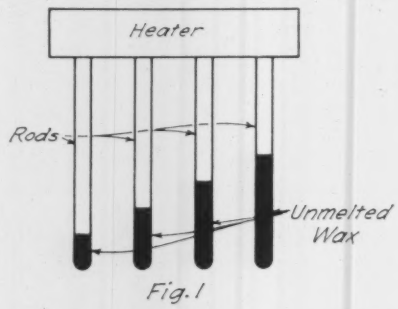


Fig. 1

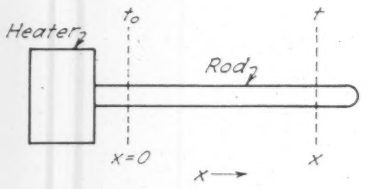


Fig. 2

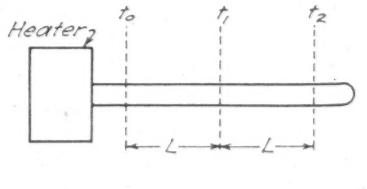


Fig. 3

dimensions must be identical.[2] A similar method is that shown in Fig. 4, where heat is supplied to two rods from both ends. Since finite rods are involved, and temperatures are read at only the two initial points and the center, the equations are slightly simplified. As the diagram shows, the two initial temperatures are the same. Wiedemann and Franz, following the same principle as Despretz, devised a more accurate method.

Another method for finding the conductivity of cylindrical rods or bars is that devised by Searle. It is a simple procedure and is extensively used in college physics courses. The rod is heated at one end by means of a steam bath and the other end projects into a cooling chamber in which cold water circulates. By measuring the temperature of the cooling water at the entry and exit of the cooling chamber, and observing the temperature at two points along the bar, the conductivity of the bar may be determined. The entire apparatus is completely enclosed by some non-conducting material like cotton, wool, cork, etc. The radiation losses inherent to Searle's method were overcome by Berget, who surrounded the bar with a ring of material so arranged that the temperature distribution along the ring was identical with the distribution along the bar.

Other and similar methods used to find k values for solids by employing rods are those of Honda and Simidu, who used rods in which were embedded small electric heaters, the whole being heavily heat insulated; and those of Donaldson, who likewise used an electrical method of heating. Schofield improved on the method of the former, enabling k to be measured up to 700 C. Lees and others also used an electrical method. By using this method Lees was able to obtain the conductivities of metals down to the temperature of liquid air.

F. Kohlrausch in 1898 used a method of finding the heat conductivity of an electrically conducting rod (Fig. 5). This method has been used by many experimenters, among the more prominent being W. Meissner, Simidu, and Masumato. Jaeger and Diesselhort found empirically that in order for heat losses in Kohlrausch's experiment to be almost eliminated the method must be arranged so that $t_1 - t_a$ equals $6 \div (t_1 - t_0)$.

Mendenhall and Angell used hollow metallic electrical conducting cylinders instead of solid rods. If the current density, the drop in potential per unit length, the inner and outer cylinder wall temperatures and the dimensions of the cylinder be noted, the conductivity of the cylinder can be calculated. Langmuir as well as Angell used this method for measuring conductivities at high temperatures.

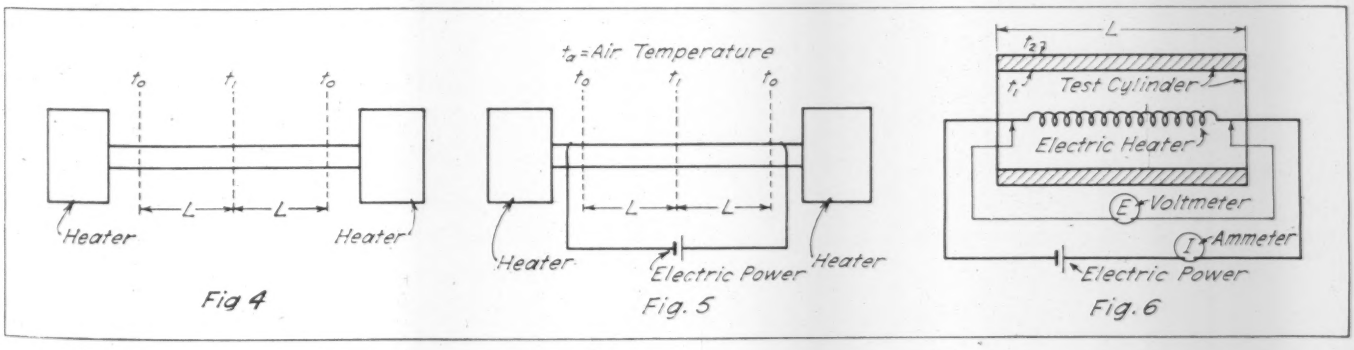
[2]Unless otherwise noted, in all cases, a steady state (that is, unvarying temperature with time) must be reached before temperatures are recorded.

Cylinder Method—The cylinder method of measuring k was possibly first used by C. Niven and later by J. K. Clement and W. L. Egy. As shown in Fig. 6, the method consists in heating electrically at the axis of a cylinder, and maintaining the temperature of the outer cylinder wall constant at t_2. After steady state prevails, readings are taken of E, I, and t_1 (volts, amperes, and temperature). With a knowledge of these values, the electrical equivalent of heat, and the cylinder dimensions, the conductivity of the cylinder can be determined. This method offers some difficulty, as end losses and radiation losses must be eliminated. Thermocouples for the measurement of temperature must also be placed so as to conduct away a minimum quantity of heat. Rinsum modified Niven's apparatus, taking into account or correcting for many losses. This method was also used in a modified form by Stephens.

Although possibly Niven was first to use large cylinders for measuring k for solids, a method given by Andrews and employed by A. Schleiermacher in 1888 used capillary tubes with a tungsten or platinum central wire as heaters to determine conductivities for gases and organic liquids. A gas or liquid was placed in the capillary surrounding the heating wire and k was computed from a theoretically derived equation that involved measurable factors. A. Eucken, and also R. Goldschmidt, used metallic capillaries in their determinations of k for liquids, being thereby able to determine more readily the inside temperature of their tubes. Sophus Weber, and also Gregory and Archer, at about the same time improved on Schleiermacher's method by using a wheatstone bridge arrangement to correct for (by balancing out) open end effects of the capillary tubes.

A. Berget in 1888 employed co-axial copper cylinders filled between surfaces with the liquid of which k was to be measured. He corrected for radiation end losses, which were relatively large, in his determination of k for mercury. Similar methods were used by Winkelmann and Bridgman, the latter investigating the variation of conductivity with pressure. E. Schmidt and W. Sellschop in 1932 used vertical copper cylinders, the inner cylinder being 30 mm in outer diameter and the outer cylinder being 31 mm in inner diameter, filled between cylinders with the liquid. The tubes were 100 mm long, had copper lids on the ends and the whole immersed in water kept at a constant temperature. The tubes as before were heated by means of a central electrical wire. In this case k for copper must be known. The layer of liquid itself was in the calculation thought of as a "plate" of liquid.

[*A second article will describe methods using plates, spheres and prisms.*]



Survey Shows 11,676 Railway Cars Air Conditioned at Close of 1938

836 Cars Conditioned Last Year

ACCORDING to a survey representing 100 per cent of the railroad field, there were 11,676 air conditioned railway cars in the United States December 31, 1938. Of this total, 836 cars were conditioned last year. The survey was made by *Railway Electrical Engineer*, to which publication we are indebted for the figures given in the tabulations on this and the opposite page.

Summary of Railway Cars Air Conditioned in 1938

Railroad	No. of Cars	Type of Car							Type of System				Refrigerant Used		
		Coach	Combination	Dining (Note A)	Chair (Note B)	Observation	Sleeping (Note C)	Business	Electro-Mech.	Direct Mech.	Ice	Steam Ejector	"Freon"	Water	Ice
A. T. & S. F.	44			12	32							44		44	
A. C. L.	25	25										25		25	
Can. National	144	65		20	2		57				144				144
Can. Pacific	90	42		23	1		24				90				90
Central of Georgia	11	8	3									11		11	
C. & E. I.	3	1	2									3		3	
C. M. St. P. & P.	49	29	4	6	10					7		42	7	42	
C. R. I. & P.	12	10		1				1		11	1		11		1
D. L. & W.	2							2			2				2
Great Northern	10	7		2				1			10				10
Lehigh Valley	1			1					1				1		
M. St. P. & S. Ste. M	2						2				2				2
M.-K.-T.	20				20							20		20	
Mobile & Ohio	2			2						2			2		
N. Y. C. System	8	2		6					8				8		
N. Y. N. H. & H.	50	50							50				50		
Norfolk & Western	5	5							5				5		
Northern Pacific	12	9		2	1					12			12		
Pennsylvania	5	2		3					3	2			5		
Pullman Co.	216				8		208		1	177	4	34	178	34	4
St. L.-S. F.	12	2	6		4					12			12		
Seaboard A. L.	4	4								4			4		
Southern	106	79	27									106		106	
Union Pacific	3			2				1		3			3		
	836	340	42	80	78		291	5	68	230	253	285	298	285	253

Note A—Includes lounge-diners, coach-diners, cafe chair, cafe coach, kitchen coach and buffet cars.
Note B—Includes lounge-chair, coach-chair and observation-chair cars.
Note C—Includes lounge- and observation-sleepers.

Safety Valves for Unfired Pressure Vessels

Why, asks a reader of HPAC, does the ASME code for unfired pressure vessels specify that the size of a safety valve for air receivers shall not exceed 3 in. in size with a relieving capacity as given in Table U-1 of the code? There are larger valve sizes made, which would mean in the case of large compressors that fewer valves would be required, and could relieve the maximum cubic feet of free air that could be supplied per minute by an air compressor.

Reply (by a member of the code committee)—It was the idea of the committee that it will be preferable not to have too great a relieving capacity in order to avoid any possible damage that might be done by the opening of an exceedingly large valve, and 3 in. was deemed a reasonable limitation.

In addition, it is pointed out that 4 and 4½ in. sizes of safety valves have been the maximum customarily used in steam and boiler operation for a great many years apparently because of the damage that may result from chattering or too quick closing in very large size valves. It is believed the same consideration governed when the rules for unfired pressure vessels were used except that the maximum limitation was placed at 3 in. in order to be on the safe side.

If developments in the design and capacity of large air compressors seem to indicate the necessity for a change in limitations, the boiler code committee will be glad to consider any such request.

Fire Hazards in Buildings

Fire protection in buildings which have air conditioning or ventilating systems came up for informal discussion at a recent meeting of the Illinois chapter of the ASHVE. John Neale of the Underwriters Laboratories and J. T. W. Babcock of the Western Factory Insurance Association indicated that insurance interests are quite concerned with the problem, and said that some 25 fires in "air conditioned buildings" had occurred throughout the U. S. during the past two years. The point that gives concern is not that these fires were caused by the fact that the buildings had duct systems, but rather that duct systems provide a path for smoke and flame. It is the opinion of insurance people, based on records of such fires, that the property damage in a building with an extensive duct system may, if suitable precautions are not taken, be a great deal higher than for a comparable building without a duct installation. Whether or not the ventilating or air conditioning system is in operation

Nine Year Summary of Air Conditioned Railway Cars

Railroad	Total Cars		Type of Car							Type of System				Type of Refrigerant		
	Dec. 31, 1937	Dec. 31, 1938	Coaches	Combination	Dining (Note 1)	Chair (Note 2)	Observation	Sleeping (Note 3)	Business	Electro-Mech.	Direct Mech.	Ice	Steam Ejector	Freon	Water	Ice
Alton	25	25	4	4	9	6	2			25				25		
A. T. & S. F.	262	306	26	6	77	174	18	5		1			305	1	305	
A. C. L.	109	134	106		28					11			123	11	123	
B. & O.	372	372	225	55	75	6	10		1	372				372		
B. & M.	90	90	82	4	4					30		60		30		60
Can. National	253	397	125		76	18		178				397				397
Can. Pacific	305	395	50	4	79	15	6	236	5			395				395
Central of Georgia	44	55	46	6	2				1			1	54		54	1
C. R. R. of N. J.	23	23	17	2	4					23				23		
C. & O. (Incl. P. M.)	113	113	79	14	12				8		104		9	104	9	
C. & E. I.	31	34	22	5	7						2	5	27	2	27	5
C. & N. W.	196	196	115	16	37	28				12	110	74		122		74
C. B. & Q.	151	151	84	8	36	4	5	14		113	4	34		117		34
C. M. St. P. & P.	247	296	142	9	55	27	4	57	2		21	275		21	275	
C. R. I. & P.	150	162	69	4	38	46	4		1	18	26	106	12	44	12	106
D. & H.	6	6			6							6				6
D. L. & W.	54	56	40		12		1		3	17	23	16		40		16
D. & R. G. W.	49	49	28		12		7		2			49				49
Erie	40	40	30		7				3	1			39	1	39	
Fla. East Coast	32	32	22		10								32		32	
Great Northern	63	73	42		28				3		12	61		12		61
G. M. & N.	12	12	5		2			4	1	7	5			12		
Illinois Central	160	160	99	10	35	10	2		4	12	135	13		147		13
Lehigh Valley	15	16	4		8	4				16				16		
L. & N.	135	135	119		16								135		135	
Maine Central	17	17	15	2								17				17
M. St. P. & S. Ste. M	9	11			3		4	4		7		4		7		4
M.-K.-T.	26	46			12	28	5		1	6		3	37	6	37	3
Mo. Pac.	273	273	101	31	58	63	11		9	26	1	206	40	27	40	206
Mobile & Ohio		2			2						2			2		
N. C. & St. L.	31	31	25		6								31		31	
N. Y. C. System	312	320	183	1	132	2	1		1	247	58	15		305		15
N. Y. C. & St. L.	21	21	15		4				2		21			21		
N. Y., N. H. & H.	387	437	379	17	35	6				304		133		304		133
Norfolk & Western	120	125	89	19	11				6	115		6	4	115	4	6
Northern Pacific	83	95	46		30	3	14	2			95			95		
Pennsylvania	605	610	338	105	167					188	2	419	1	190	1	419
Pullman Co.	4,839	5,055			9	399	494	4,153		188	3,097	1,356	414	3,285	414	1,356
Reading	63	63	41	11	9		2			63				63		
R. F. & P.	25	25	14	2	8				1	13	9	1	2	22	*2	1
St. L.-S. F.	102	114	46	10	28	21	2	2	5	1	22	91		23		91
Seaboard A. L.	95	99	51	17	27				4	4	95			99		
Southern	36	142	81	27	34								142		142	
Southern Pacific	399	399	169	2	103	113	4		8		100	225	74	100	74	225
Texas & Pacific	61	61	39		12	4	4		2	1	9	21	30	10	30	21
Union Pacific	318	321	63		85	129	37	5	2	26	231		64	257	64	
Wabash	66	66	18		18	27			3			66				66
Western Pacific	15	15	7		5		3			3			12	3	12	
Total	10,840	11,676	3,301	391	1,473	1,133	640	4,660	78	1,850	4,184	4,055	1,587	6,034	1,862	3,780

Note 1—Includes lounge-diners, coach-diners, cafe-chair, cafe-coach, kitchen-coach and buffet cars.
Note 2—Includes lounge-chair, coach-chair and observation-chair cars.
Note 3—Includes lounge and observation-sleepers.
Note 4—Total for direct mechanical systems includes 323 cars on which the compressor is driven by a gas engine.

apparently makes no difference in the extent of the damage, judging from the recorded fires.

J. B. Finnegan, professor of fire protection engineering at Armour Institute of Technology, stated that air conditioning or ventilating of buildings is not condemned by insurance people because of the fire hazard, but that the point to be remembered is that—as with other building features—the fundamental "principle of subdivision to avoid impairing the integrity of fire stops" should be observed insofar as is practically and economically possible. Samuel R. Lewis, consulting engineer, illustrated such subdivision by a hospital installation which has a fusible link fire damper at each floor level in each duct—an expensive precaution, as access doors were required at each damper not only in the duct, but also in the duct enclosure for inspection or necessary repairs. In the discussion it was stated that it should not be implied that insurance authorities necessarily recommended an automatic fire damper at each floor level, for a much smaller number of dampers should be adequate.

Mr. Lewis suggested that there was an opportunity for inventors to devise something better than fusible links, which may let go and shut off the air supply when they are not supposed to, and to improve hinges for such fire dampers, which may corrode and prevent the damper from closing when it should.

Fire insurance underwriters have insisted on compliance with the following clauses in many recently built fireproof buildings, according to Mr. Lewis: (1) Install a thermostat in the airway at the inlet of each exhaust fan, and another in the airway at the outlet of each air filter, set to operate at 125 F which shall cause the opening of the respective motor circuits and the simultaneous closing of dampers which will prevent air passage to or from the fans, these arrangements to be such that failure of power leading to the thermostat shall cause closure of the dampers. (2) In other cases, the release of automatic sprinklers or of carbon dioxide from special drums in response to thermostatic action has been required.

The National Fire Protection Association, 60 Batterymarch St., Boston, Mass., issues a booklet "Regulations for Air Conditioning and Blower Systems" (price, 15c) which is revised yearly. These regulations—like the NFPA's other standards on various phases of fire protection and fire prevention—are designed to secure reasonable safety from fire without working any unnecessary hardship, according to Robert S. Moulton, technical secretary of the association. The committee responsible for the regulations is completing the 1939 revisions, which are to be submitted to the NFPA for adoption at its annual meeting to be held in Chicago May 8 to 12.

Some Fundamentals of Psychrometry

By Serge J. Zaroodny*

A brief review of some fundamentals of psychrometry, with a comparison of the dewpoint and the adiabatic saturation methods, and with a distinction between the adiabatic saturation and the wet bulb temperatures

IN the solution of problems involving the moisture and heat content of air there are two distinct methods: the humidity can be expressed either in terms of the dewpoint or in terms of the wet bulb (adiabatic saturation) temperature. Analogously, the heat content can be expressed either in terms of enthalpy or in terms of Carrier's *sigma function*. The method of using the dewpoint and the enthalpy has the advantage of directness, as fewer definitions are required. The method of using the adiabatic saturation temperature and the sigma function, although introducing several additional concepts, is of particular help in the solution of problems related to evaporative processes.

As we vary the temperature of a given sample of air (at the same barometric pressure) the quantities that remain constant (besides, of course, the ratio of the weights of water vapor and air) are the dewpoint and the partial pressure of the water vapor.[1] The direct measure of the dewpoint would therefore seem to be the most logical way of determining the moisture content of air, if we were concerned with this alone. Unfortunately, this measurement requires sensitive apparatus and considerable skill in noticing the exact moment of the formation or disappearance of the dew.

The dewpoint is a definite property of air, i. e., it does not depend upon the temperature of the air. We speak of air at 150 F as having a dewpoint of 40 F, meaning that it will form dew *if* cooled to 40 F. However, in actual practice of dewpoint measurements, we note the temperature at which the dew forms on an artificially cooled mirror surface; in such a case there is naturally a certain heat flow from the air to the surface and due to the resistance to this heat flow (through the dew itself as well as through the apparatus) the dewpoint thus measured will be inherently too low. This inherent inaccuracy of the dewpoint measurement can be reduced by cooling the given sample of air to near the dewpoint before measuring the latter. Incidentally, recent researches show that the dewpoint measurements are further complicated by the fact that the reflection of the light at the mirror surface is affected not only by the dew as such but also by the film of cold air at the surface.[2] Nevertheless, the dewpoint is the most vivid way of indicating the moisture content of the air, if not a direct measure of this content.[3]

The additional concepts used in calculations of the moisture content are the concept of relative humidity, as ratio of vapor pressures; the saturation curve (the curve of saturated vapor pressure vs. temperature, or, for a given barometic pressure P, the curve of specific humidity vs. temperature); the formula[4] for expressing the specific humidity w (the pounds of water vapor per pound of dry air in the mixture) in terms of vapor pressure p, $w = 0.622\ p/(P - p)$; the specific heat of air (0.24) and of water vapor (0.45); and the latent heat of water vapor. These concepts might be sufficient for most psychrometric calculations. The method of employing these concepts only, could be characterized by the fact that it deals separately with the two components of the heat content of the air—*sensible* heat ("sensed" by the thermometer) and *latent* heat (the heat of evaporation of the moisture in the air, proportional to the moisture content of the air, and not sensed by the dry bulb thermometer).

Psychrometric Method—The practical and common method of determining the moisture content of the air is by taking a simultaneous reading of two thermometers, a dry bulb and a wet bulb. The main advantage of this method—the simplicity of the measurements—is obvious. While this method is over a century old, its present usefulness dates from 1911, when Carrier correlated the psychrometric measurements to the heat content of the air. This method was formulated for, and in its usual form applies to, only the measurements of the water vapor in the air—which, however, is usually the case. In its usual form this method is due to two fortunate coincidences.

This method is based on the concept of the adiabatic saturation temperature, which, like the dewpoint, is a definite property of air (see below). The essential characteristic of this method is that with it, while the dry bulb determines the sensible heat of air, the wet bulb determines the *total* heat (the sum of the sensible and the latent), so that the latent heat can be figured as the difference between the total and the sensible heat. In other words, this method ties the temperature and the humidity measurements together.

Adiabatic Saturation—With the dewpoint method, varying the temperature of air with constant moisture content is a fundamental process—during which the dewpoint remains constant. With the psychrometric method, such a fundamental process is *evaporative cooling*, or more strictly, adiabatic saturation. In this process both temperature and humidity vary, but the temperature of adiabatic saturation remains constant; the dry bulb temperature is lowered because the latent heat of vaporization of water must come from the air. In other words, the high temperature sensible heat of air is transformed into low temperature latent heat of water vapor; accordingly, the process can go only one way.

*Municipal Architect's Office, Washington, D. C.

[1]This latter, as well as the ratio of weights, could be measured by absorbing all of the water vapor from the given sample of air by some chemical means.

[2]This makes the observed dewpoint still lower. The exact dewpoint should be observed as only a slight break, not visible to the eye, in the curve of the amount of light reflected by the surface.

[3]The curve of the moisture content vs. dewpoint (saturation curve) is very nearly an exponential curve, doubling approximately every 50 F, so that at higher temperatures a degree increment in dewpoint means a higher increment in the moisture content than at lower dewpoints.

[4]This formula is derived by combining the law of partial pressures ($P = p_{air} + p_{vapor}$) with the ideal gas equation $pv = WRT$, written separately for 1 lb of air and for w lb of vapor occupying the same volumes v and being at the same temperature T.

The word *adiabatic* means that there is no heat flow between the surroundings and the matter in question, in this case the *whole system* of air and water (vaporized as well as liquid). The true total heat, or the *enthalpy* of the *moist air* in this case is slightly increased by the enthalpy of the liquid water which evaporated into the air. That heat content of the moist air which remains constant during this process was termed by Carrier *sigma function*. Psychrometric calculations can be based equally well on the enthalpy or on the sigma function, and each method has its advantages.

Adiabatic Saturation and Wet Bulb—The whole point of the psychrometric method as it is used today is that the reading of the wet bulb thermometer is taken to be the adiabatic saturation temperature.

It was proved recently that the temperature of the wet bulb is not necessarily the same as the temperature of adiabatic saturation. Although the distinction between these two temperatures is usually neglected (for the mixture of air and water), it is of sufficient general interest and importance to be noted.

The temperature of adiabatic saturation obtains when air is completely saturated by this process. This is the temperature on which the rational psychrometric formulas are based. It is a definite property of air, i. e. it does not depend upon the air velocity, radiation, etc.

A wetted thermometer bulb, when exposed to the current of unsaturated air, is evaporatively cooled: the sensible heat is given to the thermometer by the flowing gas (and by the radiation from the surroundings), and the latent heat is taken away from the thermometer by the vaporization of liquid. When the equilibrium of this heat interchange is established, the *wet bulb* temperature is reached. This temperature depends upon the air velocity, and is also affected by the radiation. If the thermometer is shielded from radiation, i. e. if the surroundings are at the wet bulb temperature, the reading may be termed the true wet bulb temperature.

The wet bulb temperature may be defined as the temperature reached by a limited mass of *liquid* when an unsaturated gas is blown over this mass in such an amount as to render negligible the change of the vapor content of this gas, while the adiabatic saturation temperature is reached by a limited mass of an unsaturated *gas* blown past such an amount of liquid as to become completely saturated. Thus the difference is merely in the degree of the saturation of the air. Actually in an air washer (with recirculated water) there occurs a partial saturation, and the wet bulb thermometer at the outlet of the washer registers a temperature intermediate between the wet bulb and the adiabatic saturation temperatures of the entering air.

With an air-water mixture, it is a fortunate coincidence that these two temperatures are nearly the same. Because of this the wet bulb temperature has long been considered as being the temperature of adiabatic saturation, and now in air conditioning parlance these two terms have become practically synonymous.

The true wet bulb temperature for water is slightly lower than the adiabatic saturation temperature (10 to 17 per cent of the wet bulb depression at zero air velocity, but this difference decreases with higher air velocities). In other words, it is possible to cool the water in a cooling tower to a slightly lower temperature than that to which we can cool the air by spraying it with recirculated water.

It should be noted also that the psychrometric method permits determination of vapors other than water as well, and a selective determination at that. By wetting the wick of the wet bulb thermometer in, say, benzene, we can (with certain limitations) determine the benzene content of the air independently of its moisture content, which is not possible with the dewpoint method. In such a case, however, we must use the exact wet bulb

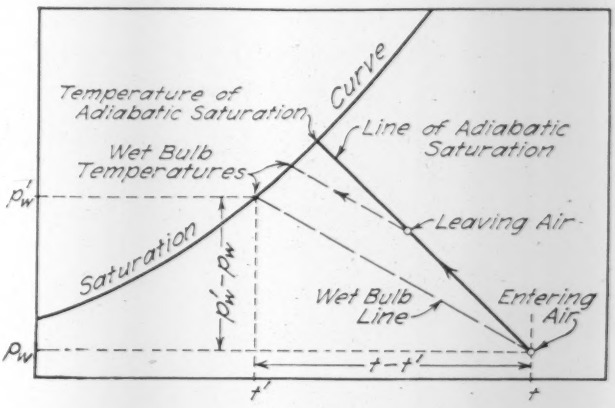


Fig. 1—The wet bulb and adiabatic saturation temperatures of the air. The relationship is shown for water and is exaggerated for the sake of clarity. For other liquids the wet bulb temperature is considerably higher than the temperature of adiabatic saturation

theory (and not the rational psychrometric formulas analogous to those used with water vapor).

With mixtures other than air and water, the wet bulb temperature is generally higher than the adiabatic saturation temperature; that is, considerably greater cooling effect may be obtained by complete saturation of the air. For example for toluol the toluol-dry air at a dry bulb temperature of 79 F has a wet bulb temperature of 58 F and an adiabatic saturation temperature of 45 F. This may be explained by the fact that the evaporation is essentially a molecular diffusion process, and that the molecules of water (which of all the liquids has about the lowest molecular weight) are more agile and apt to diffuse into the air than are the heavier molecules of organic liquids.

The best criterion to be employed in psychrometric calculations is the adiabatic saturation temperature, particularly because in air conditioning practice the psychrometric observations are of secondary importance to the thermal calculations. Therefore, the object of the psychrometric measurements usually is to determine the temperature of adiabatic saturation, rather than the wet bulb temperature as such. For the same reason, it may be desirable to use for psychrometric measurements some apparatus which would produce complete saturation of the air (such as bubbling the air through the liquid). However, (and for an air-water mixture particularly) the usual practice is to use the wet bulb thermometer,

[*Concluded on p.* 298]

Oxy-Acetylene Welding Developments Described at IAA Annual Convention

DEVELOPMENTS in oxy-acetylene welding were described at the recent annual convention of the International Acetylene Association held at the Rice hotel in Houston, Texas. The following paragraphs are excerpts from some of the papers presented at the meeting.

Welded High Pressure Piping, by Arthur N. Kugler[1]—The term "high pressure" as applied to piping is subject to many interpretations. For the purposes of his discussion, Mr. Kugler considered pipe ½ in. thick and greater as high pressure piping. In order to evaluate relative physical properties of welds produced by various methods, it is necessary to know something of the methods of testing pipe welds. There are the familiar reduced section tensile test, the free bend test, the reverse or back bend test, and the nick break test. A relatively new test is the restricted or guided bend test that has been used by the navy department with excellent results. The bends are made in a jig proportioned in terms of the specimen thickness, the jig consisting of a die and plunger which forces the specimen into a U shape. When the face or top of the weld is in tension it is known as a *face bend*, while with the root in tension it is a *root bend*. The requirements for this test are simple, and therein lies one of its principal advantages; it is merely that the specimens, both their face and root, bend to the full capacity of the jig.

There are various methods of pipe welding, the oldest perhaps being the forehand or puddle welding method. In this the torch and rod are disposed so that the torch flame points ahead of the completed weld and the rod precedes the torch. The backhand technique—also known as carburizing flame welding—was developed about 10 or 12 years ago. In it the torch and rod are so disposed that the torch flame points back at the completed weld and the rod is interposed between the torch and weld. Backhand welding of the thinner wall thicknesses up to about ⅜ in. is a standard operation with many concerns and in this the weld is made in a single layer or pass. The welding of pipe greater than ⅜ in. thick in one layer, whether by forehand or backhand welding, presents some difficult problems, he said, the principal one being the large puddle of molten metal which must be maintained. To overcome such troubles, multilayer welding was developed and, as the name indicates, involves the deposition of weld metal in layers. It should not be confused, however, with the somewhat similar arc welding technique. The layers of the former bridge from one side of the vee to the other; in the latter, except for the first few beads, the deposited metal does not usually span the vee.

Oxy-acetylene stress relieving—heated joint covered with block asbestos

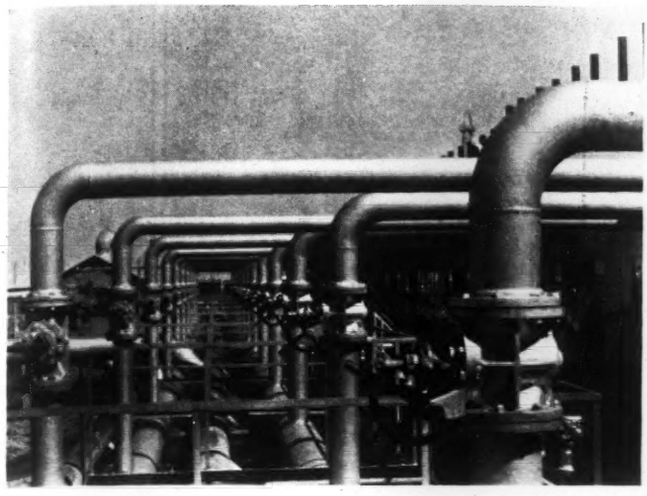
Mr. Kugler then compared the welding of carbon-molybdenum steel pipe by arc welding and oxy-acetylene welding. He stated that an oxy-acetylene welding rod of carbon-molybdenum analysis has been developed and is now undergoing field tests, the results of which are most promising. He said that since this pipe is of heavy wall thickness, multilayer welding is employed with the backhand technique. He gave comparisons of the arc welding and oxy-acetylene procedures for welding such pipe and laboratory test results on welds.

An important phase of the procedure for welding high pressure piping is stress relieving, the primary purpose of which is to relieve the welded assembly of locked up stresses, but in addition, to provide a measure of grain refinement—all of which is reflected in an increase of weld ductility. The actual heating is carried out in several different ways, depending on conditions. In a recent large installation on which stress relieving was specified on extra heavy pipe, the following procedure was employed. The weld and adjacent pipe were heated uniformly with multiflame oxy-acetylene torches to 1450 F, which temperature was checked by pyrometer. When the joint reached the desired temperature, heating was stopped and it was wrapped with asbestos blocks or paper, the ends plugged if open, and allowed to cool slowly.

New Developments in Welding Fittings, by E. Hall Taylor[2]—New developments in welding fittings have come about so gradually that most users are not aware of the type changes and of the improvements in fittings that are now available, according to Mr. Taylor. Of first importance from the user's standpoint, he said, is the new proposed standard for welding fittings which covers the overall dimensions of the fittings in elbows, tees, caps, reducers, return bends, and lap joint stub ends. It also covers the pressure ratings, size, marking, material, metal thickness, tolerance and the welding bevel. The angle of the bevel for butt welding has been agreed upon in this standard as 37½ deg, which has been in use in pipe line work for some time. As fast as changes can be made, the 37½ deg bevel will be adopted on welding fittings, he stated. The narrow groove formed by this bevel has the advantages of requiring less weld metal.

[1]Mechanical Engineer, Air Reduction Sales Co.

[2]Vice-president, Taylor Forge and Pipe Works.



A welded piping installation

Welding small diameter pipe has always presented a problem in lining up and in welding, he said, as the wall thickness of pipe 2 in. and under is of course comparatively thin and when this is bevelled for welding, the narrow bevel is not easy to line up with the pipe. Also, welding the thin wall requires care to avoid burning through. The development of socket welding fittings several years ago solved these difficulties and these fittings have come into widespread use.

The reinforcing of branch connections attached to pipe by welding has assumed such importance that a committee has been formed to study this in connection with the code for pressure piping. Extensive tests are being run to determine just what the strains are and what reinforcements are necessary when a hole is cut in a pipe for a branch connection.

Mr. Taylor described various features of welding fittings, such as their use in the forming of expansion loops, design of the hub on butt weld flanges so there is no danger of the welding heat warping the face of the flange, identification markings on fittings, marking center lines on elbows to simplify determining the angle at which the fitting should be turned so as to fit the next run of piping, and centering rings as part of the welding fitting, which also act as backing up rings for the weld metal. He concluded by saying that "we have only begun to see the developments in welding and in welding fittings."

Latest Practices in the Pipe Line Field, by W. B. Poor[3]—According to Mr. Poor, a review of the progress made in the pipe line field during the last 12 to 18 months indicates three major phases of advancement: (1) improvements in welding facilities with particular respect to new and improved tips and rod, (2) the field stress relieving of arc welds, and (3) the development and acceptance of wrinkle bending.

He described the four flame and the six flame welding tips. In the first, two small parallel flames are used to preheat the pipe ahead of the welding puddle, a third and larger flame preheats the welding rod, while the fourth flame accomplishes the actual welding. The six flame tip is similar, with the exception that it has two additional preheating flames.

[3]Engineer, United Gas Pipe Line Co.

Development of the composition of welding rods has been aimed toward higher strength and greater ease of control in the welding operation. A new rod has recently been designed to give tensile strengths 10,000 to 12,000 lb per sq in. greater than with rods previously used in pipe line welding and yet to retain sufficient ductility to meet normal requirements. In the field stress relieving of arc welds, it has been found that certain types of this work can be effectively and economically done by an oxy-acetylene flame.

The most interesting development in recent years in the field of pipe line construction is the development of the practice of wrinkle bending, according to Mr. Poor. This is a modification of the creased bend and corrugated tangent which has been in use in the fabrication of power piping. He said that the wrinkle bend may be readily applied on any sag bend, over bend or side bend, and that its use eliminates unwieldy equipment and a large portion of the labor cost incurred by a large bending crew. It also overcomes one of the main objections of the pipe line constructor to the use of light wall high carbon pipe, since bends may be made in the field on such pipe with the same degree of ease that such a bend may be made on mild steel pipe.

The preparation of the wrinkle bend is comparatively simple and the procedure is essentially the same for all sizes of pipe, he stated. It consists in heating with a regular oxy-acetylene blowpipe one or more narrow bands of metal at right angles to the longitudinal axis of the pipe. The large capacity multiflame blowpipe, designed for heavy heating operations, is particularly adaptable to this work. On pipe under 6 in. in diameter one torch supplies sufficient heat to prepare the pipe for bending. On pipe 6 in. in diameter and larger, a more satisfactory bend is made with the use of two flames and on sizes 10 in. above, such practice is essential. The band of heat should be 2 in. to 3 in. wide at the point of bending and should extend equidistant from the point of bend until the heated band extends one-half to two-thirds the circumference of the pipe, tapering to a point at the termination of the heated area. The pipe should be heated to a bright red, at which temperature the critical range of the metal is reached and the pipe is not strained as in cold bending. At this point the pipe is bent by hand, tractor, or bending rig until the heated portion buckles sufficiently to give the pipe a predetermined offset bend.

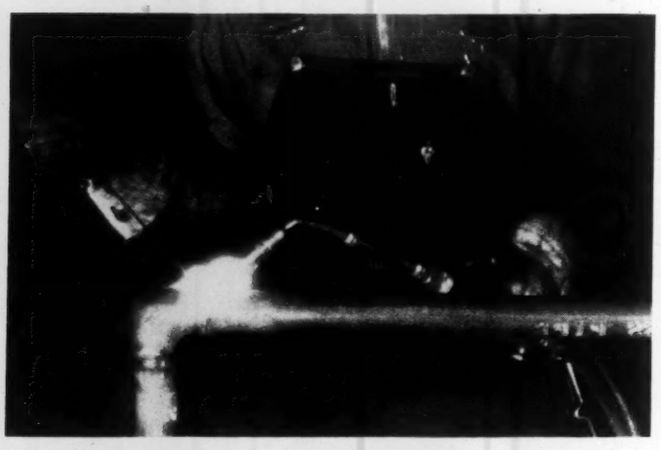
Good practice would seem to indicate that a 5 deg bend per wrinkle is a maximum and that a 2 deg to 3 deg bend per wrinkle is better, he said. The number of wrinkles indicated, therefore, is predetermined by the total degree of bend required. At no time during the process of making the bend, or afterward, should the pipe be artificially cooled or quenched. Should high carbon pipe be artificially quenched, in all probability the bend or wrinkle will crack due to sudden chilling of the metal. If possible, the spacing of the wrinkles should be at least one pipe diameter apart. This is, however, not mandatory as 24 in. Grade B seamless pipe, having a wall thickness of $\frac{5}{16}$ in., has been successfully bent approximately 28 deg with 5 deg wrinkles spaced 8 in. on center. Such practice should be followed only in special cases.

Use of Oxy-Acetylene Welding in the Plumbing, Heating and Air Conditioning Contracting Fields, by Frank E. Wallace[1]—Mr. Wallace reviewed welding in heating and air conditioning contracting work and described some of the installations with which he is familiar. One of the latest is the Andrew Jackson housing project at Nashville, Tenn., completed in 1938. On this job all outside yard lines, amounting to more than 7 miles of pipe, were welded. The installation is particularly interesting because all of the yard piping was insulated by a process which consists of applying a standard type of insulation to the pipe, over which a fairly heavy layer of asphalt is cast in a light weight sheet metal jacket which acts as a protector to the insulation while the insulated pipe is in transit and during the installation. As shipped, each length has the insulation stopped short at the ends of the pipe for threading and the attachment of fittings. It was thought that this type of insulated pipe installation might not be suitable for welding as the heat would cause the asphalt jacket to run. This proved not to be the case, however, and a most satisfactory installation was made, he said.

Piping is not the only place for welding in air conditioning. The heavy condensers, coolers, air conditioning units, and cooling towers require steel supports and cradles. Here, welding serves the contractor in the speed and economy of fabrication and erection. Coolers and condensers, with their immense weight, are usually supported from concrete floors in basements; but cooling towers, in spite of their size and weight, must necessarily be situated on the roofs of buildings. No normal building was ever designed with a roof capable of this abnormal loading, he said. It is therefore necessary in most installations to go below the roof deck and extend the building columns up a distance above the roof and then band them together with heavy steel beams carrying an I beam grillage to support the pan of the tower. This is done because of the fact that a large percentage of the buildings now having air conditioning systems installed in them are old buildings—that is to say, they are buildings that have already been built without the proper preparation having been made for the accommodation of the cooling tower. Welding is most useful here, where it would be practically impossible to rivet on a column extension, and where the noise of a riveting hammer would be objectionable to occupants of the building.

[1] C. Wallace Plumbing Co.

Welding socket elbow into a line



Psychrometry—

[*Concluded from p. 295*]

correcting its readings if necessary to give the temperature of adiabatic saturation.

Radiation Effect—An ordinary wet bulb thermometer not protected from the radiation of heat from surrounding objects, which are usually at the dry bulb temperature, registers a slightly higher temperature than a thermometer shielded from such radiation. This effect becomes very great at low velocities.

To offset the radiation effect, the air must be blown past the wet bulb with sufficient velocity to evaporate enough liquid so that the relative influence of the radiation will be reduced; besides (and what is more important, as shown by J. H. Arnold), at higher velocities the very mechanism of evaporation is such that it gives a true wet bulb temperature nearer to the temperature of adiabatic saturation.

A wet bulb thermometer may be also so constructed as to eliminate the influence of radiation (Assman's aspiration psychrometer); it is also possible to estimate the correction for the radiation as a percentage of the wet bulb depression, and to subtract it from the wet bulb reading.

However, in the usual practice with the air-water mixture, such corrections are really unnecessary, and neither is it desirable to use a thermometer shielded from radiation, because the correction for radiation is just about cancelled by correcting the wet bulb temperature to give that of the adiabatic saturation. This is the second fortunate coincidence. It has been shown that the temperature of a wet bulb *not* protected from radiation at an air velocity of about 1000 fpm is a very close approximation to the temperature of adiabatic saturation.

Use of Ring Type Joints

Theoretically, the bolt stresses in four bolt ASA flanges are no higher than those in flanges having eight or more bolts. With a four bolt flange, however, there is always a possibility that a single bolt, or else two adjacent bolts, may be pulled up too little, or too much; and, again, one or two bolts may be overloaded or else relieved of load because of pipe line bending moments. In such circumstances the four bolt flange is at a distinct disadvantage, not only because two or three bolts must carry the entire load, but especially because the resulting distribution of pressure around the joint surfaces is conducive to leakage. For these reasons, four bolt flanges have frequently proved to be more troublesome than others.

To overcome the deficiencies of four bolt construction, one of the large American oil refineries specifies that ring type joints, which require less bolt load than other types, be used for 2 in., 2½ in. and 3 in. sizes of 150 lb American Standard steel flanges. This refinery also specifies ring type joints for 300 lb flanges for all installations where temperatures are above 600 F, and for all oil line flanges from 400 lb to 2500 lb inclusive. They avoid corrosion difficulties by specifying 4-6 chrome alloy material for the rings.—W.

Direct Fired Air Heaters Meet Requirements of Aircraft Plant

By H. E. Ziel*

THE large aircraft assembly plant recently erected for the Glenn L. Martin Co. near Baltimore, Md., presented unusual problems for properly controlled and uniform heating, because of the large floor space, the great clearance height from the floor to the roof, and the large glass areas in the side walls and in the roof. The clear floor space covers an area in excess of three acres.

The exterior of the building is shown in Fig. 1. The three large doors completely open the side of the building when raised. The roof truss above the main doors has a clear span of 300 ft. These three 100 ft doors operate individually or can be raised simultaneously. This item in itself required unusual pick-up capacity in the heating system.

The interior of the building, and one of the large planes recently completed, is shown in Fig. 2. One can readily see that the clear space required for the assembling of planes prohibited the placing of any heating equipment above the floor except at the building columns or at the outside walls. Due to the large wing span of the planes, it was not practical to heat the building with equipment in the roof trusses.

Thus, the general limitations placed on the heating system were:

No heating equipment should be placed above the floor line which would interfere with the assembling of planes.

The heating must be reasonably uniform throughout the entire building.

The heating system must have the capacity to quickly heat up the building after being cooled due to the opening of the large doors, and yet not overheat the building if the doors remain shut.

The system must be economical to operate.

The system selected consisted of four direct fired air heaters, each being capable of heating 80,000 cfm of air through a temperature range from 60 to 160 F. These heaters are installed in rooms situated under the first floor and are reached by means of pipe tunnels.

The air from each heater is circulated through a series of underfloor trenches and tunnels, the supplies terminating at diffuser outlets shown in Fig. 3 and floor outlets shown in Fig. 4. The diffuser outlets are installed between double columns which support the roof trusses. The air is discharged through the deflectors at a velocity of 1800 fpm. This high velocity causes a turbulence which allows the hot discharged air to mix effectively with the cooler room air. This mixture of hot and cold air retards the tendency of the warm air to rise, making possible an almost uniform temperature throughout the entire height from the floor line to the under side of the roof truss.

The supply outlets in the floor, shown in Fig. 4, are equipped with diffuser vanes which force the air to be discharged into the building at an angle of 45 deg with the floor line. Return grilles in the floor allow the air to be drawn back to the heater rooms for reheating.

Fig. 5 shows the heating surface of one of the heaters before the enclosing brick work was installed. The air to be heated is discharged through the 4½ in. steel tubes by means of an 80,000 cfm double inlet motor driven blower, and then delivered directly to the building. The hot gases from the oil burners pass around the tubes, making possible a rapid transfer of heat from the oil burners to the air delivering the heat to the building.

The products of combustion are drawn from the furnace by means of an induced draft fan which discharges the gases up through the roof of the building. The heaters are situated near the center of the building. The discharge duct from the induced draft fan is extended hori-

*Albert Kahn, Inc., Architects and Engineers.

Fig. 1—View of the Martin assembly plant

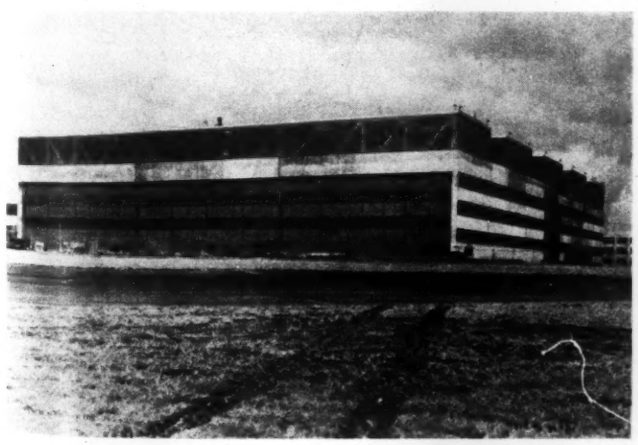
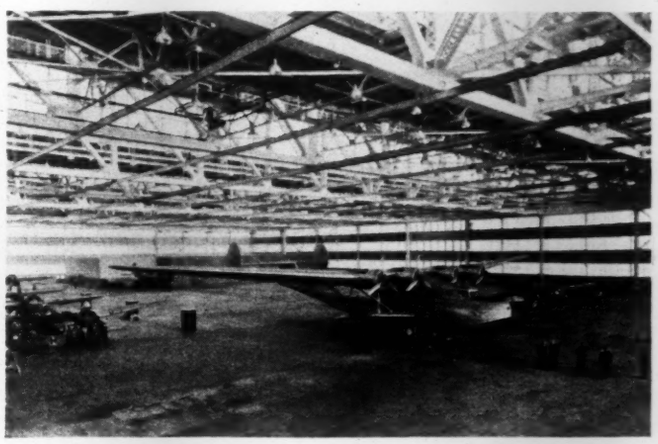


Fig. 2—Interior view of the assembly building



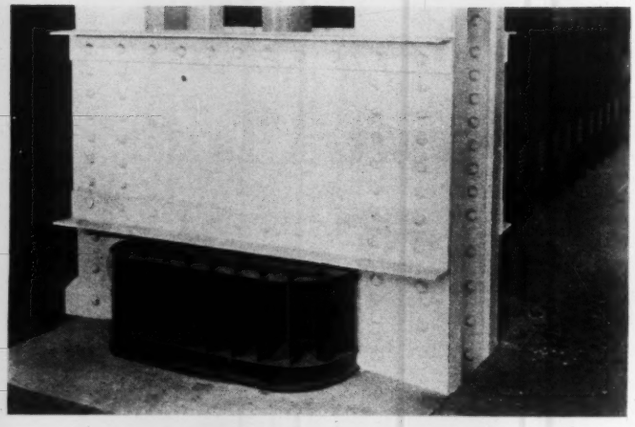


Fig. 3—These outlets between the double columns supply air at a velocity of 1800 fpm and at temperatures as high as 160 F

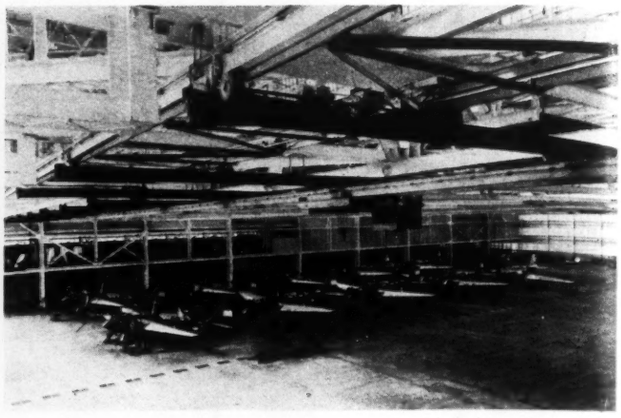


Fig. 4—Air supply outlets in the floor are equipped with diffuser vanes discharging the air into the plant at an angle of 45 deg with the floor line

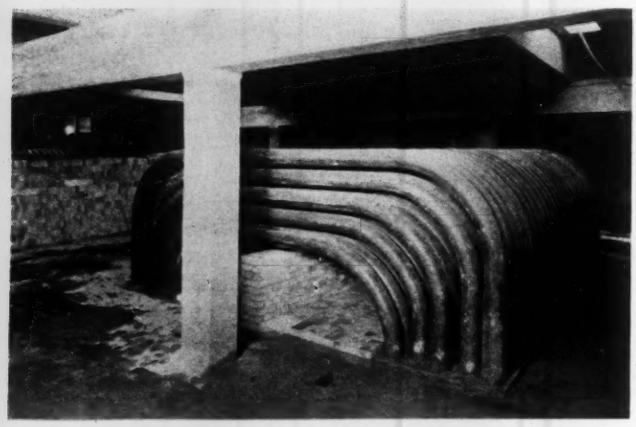


Fig. 5—The heating surface of one of the direct fired heaters

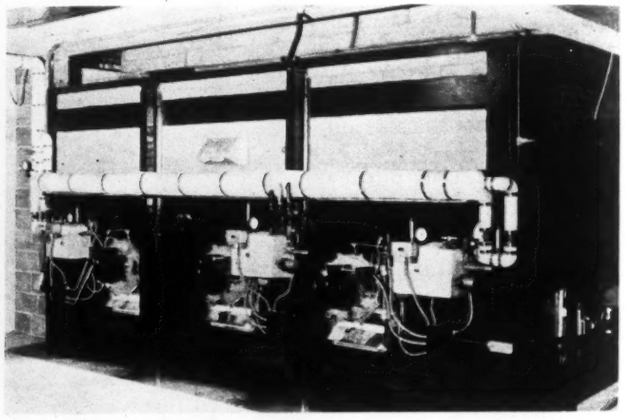


Fig. 6—One of the heaters, which is capable of heating 80,000 cfm from 60 to 160 F

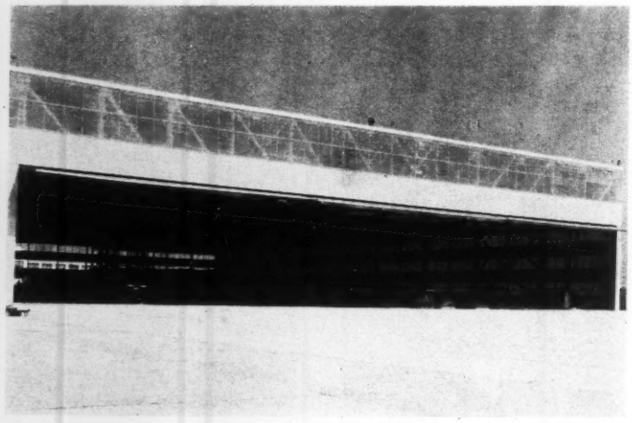
zontally in the pipe tunnel to the outside wall of the building, as the first floor area must be entirely free from obstructions. The long horizontal ducts in the pipe tunnels extending from the induced draft fans to the various vertical stacks at the side walls serve as economizers. The surfaces of these horizontal ducts temper the incoming air drawn into the pipe tunnel through air intakes in the side walls opening into the tunnel. This tempered air serves as an added supply to the building and is also used to support the combustion of the oil burners.

A front view of one of the four completed heaters, with three oil burners installed in each heater, is shown in Fig. 6. These three oil burners are controlled by thermostats making possible the rapid increase or decrease of the heat output according to the requirements. The oil burner control is electrically interlocked for safety with the induced draft fan and blower motor, making it impossible to run the oil burners without running the fan and blower motor. The induced draft fan and the large blower fan are on a common shaft driven by a single motor.

The entire heating system has proved most satisfactory after one complete season of operation. The method of discharging the warm air horizontally at the floor line, causing the warm air to mix with the cooler air, has been found to give a uniform temperature in the building. The direct firing of the heaters with the battery of thermostatically controlled oil burners eliminates lag losses and overheating.

Albert Kahn, Inc., was responsible for the design of this plant.

Fig. 7—Main assembly hall with doors open. It could accommodate three football fields and 20,000 spectators. The electrically operated doors can be raised a few inches from the floor or opened to their full width and height in 68 seconds



Some Legal Aspects of Air Conditioning

By Lawrence R. Bloomenthal*

Legal complications may arise in every field of human endeavor, and the design and installation of an air conditioning system is no exception. Because "circumstances alter cases" absolutely definite answers to all the various legal aspects involved cannot be given. The author does, however, cite pertinent court decisions and indicates some of the things to remember

IN engineering and contracting work—as in almost any activity—a variety of legal complications may arise. It is the purpose of this discussion to point out some of them and how they may be avoided.

Mistakes in Bidding—While it is not possible to give a definite and inclusive answer to the specific question of mistakes in bidding, there are many decisions that are pertinent.

In one case, a contractor bid on a sewage treatment plant, depositing a $5000 certified check as required by the rules of the Public Works Administration, which was furnishing part of the funds. The proposal contained a clause stating that the contractor had carefully examined the form of contract, the specifications and drawings, and had read the information and instructions for bidders. Since his was lowest of the eight bids, it was accepted.

On the day following acceptance, a letter was sent to the sewer commissioners asking permission to withdraw the bid because of two serious errors in figuring concrete costs. One item priced at $16.50 a yard should have been $26.50; the other submitted at $10.00 should have read $20.00. The commissioners were inclined to grant this request and refund the deposit but were overruled by the PWA authorities, who exercised supervisory powers under their loan agreement. The bidder was notified that he would not be released and must execute a formal contract and bond unless he wished to forfeit the $5000 deposit.

Instead of complying, he demanded return of the certified check and filed suit when it was not forthcoming. After the lower court ruled against him, an appeal was taken to the highest court of the state, which upheld the decision of the lower court. The opinion declared that a mistake on the part of one of the parties to a contract does not entitle him to release from his obligations. Also, under the terms of the proposal, no bidder could withdraw for 30 days after the date set for the opening of bids. The court pointed out that by signing this form, the contractor expressly bound himself to continue his offer for the stipulated period.

Once bids are in, a change in plans or specifications on the owner's part constitutes a counter offer. Unless the invitation to submit bids reserved the right to make such changes, all bidders are justified in withdrawing their offers and any bonds or certified checks posted as a deposit. Only when there is a mutual mistake of material fact (such as the amount of space to be air conditioned, for example) can either or both of the parties rescind entirely.

Delays in Completion—Purchasers of air conditioning systems frequently set a date by which the job is to be completed. Especially is this true when the addition of such a system has been emphasized in securing conventions or other public gatherings for hotels or auditoriums. Unexpected delays may bring about the cancellation of profitable bookings, particularly during the summer months.

If a clause has been included stating that "time shall be the essence of this contract," the courts will hold with the owner and require performance by the exact date set in the agreement. According to the literal wording of this clause, the engineer or architect in charge would be justified in ordering a dilatory contractor to speed up the work or be subject to dismissal.

Where the time limit specified in the contract has not been made "of the essence," a different situation exists. Then the courts look into the surrounding circumstances to determine whether there was a definite necessity for completion by that time or whether the date merely suited the owner's convenience. If a contractor is dismissed because the work did not progress rapidly enough, he has the burden of proving that he was ready, willing and financially able to complete the work even though there would have been a slight delay. Should the evidence indicate that there was no actual urgency and such a delay would not have caused substantial injury, the owner may be required to pay damages for breach of contract.

Defective Plans—Clear, accurate and complete plans and specifications must be furnished to the contractor. Recently, a construction company in a western state demanded $281,000 damages, charging that the structural and architectural plans were not in agreement with each other and that the supervising architect refused to correct or coördinate them. Therefore, it was necessary to erect a structure different than the one contracted for and this entailed heavy additional expense. The case is still pending.

The issue is similar to the situation of a firm of air conditioning engineers a few years ago. After being awarded an office building installation, it was discovered that the plans furnished by the owner failed to reveal the existence of unused plumbing and heating pipes in the walls. When the owner was notified that there would be the added expense of removing these impediments, he refused to bear any part of the cost. The contractor then suspended work on the ground that inaccurate plans had been provided and it would be impossible to take care of extra work at the agreed price. Thereupon the owner reconsidered and an amicable agreement was reached.

Recommending Materials—It is well established that

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an architect or engineer assumes no personal responsibility for the failure of recommended materials to perform satisfactorily on a particular job. His obligation is to select with reasonable care and skill the materials or machines called for by the specifications. So long as it can be shown that the equipment chosen was in successful use elsewhere for a similar purpose, no negligence is apparent.

Perhaps the only time that an engineer might be charged with lack of sound professional judgment would be when a new and untried machine was installed upon his specifications. Then, if it failed to function or needed expensive repairs and constant attention, there might be some foundation for alleging that the best engineering practice was not followed.

Dissatisfaction with Completed Job—Despite the rapid growth of the air conditioning industry, there has been comparatively little litigation carried to the higher courts. Those complaints which have arisen seem to have dealt mainly with dissatisfaction over the performance of a completed job.

According to the decided cases, air conditioning contractors making specific warranties must comply with their guarantees that the machinery will produce certain atmospheric conditions or maintain stated temperatures. Non-compliance with these warranties permits the buyer to recover damages from the seller.

Whether or not "loss of trade" can be included in the measure of damages has not yet been settled in all states. At present, the courts are in conflict on this point. Some hold that simply because a system is not functioning satisfactorily does not indicate that a merchant has lost trade thereby. Others probably will allow recovery on the theory that the seller knew or should have known that trade losses would be a direct and natural consequence of faulty performance.

Last year, the Kentucky supreme court passed on a case in which a fur company that had purchased a cooling system for its storage vaults sued for damages. Since the contract warranted that the unit would meet the purchaser's requirements as outlined and would be free from mechanical defects for a period of three years, the seller repeatedly attempted to make adjustments which were rejected as unsatisfactory. Finally, the equipment was removed upon the order of the buyer who then filed suit to recover damages for breach of contract; it was charged that certain temperatures had been guaranteed but that they had not been maintained at any time since the original installation.

In defense, the seller claimed that the entire suit was without legal basis because the buyer had not proved that the machinery itself was defective or that it was incapable of producing the guaranteed refrigeration if operated properly. According to his contention, the construction of the building and the method of operation were at fault, rather than the equipment. Upon appeal, it was decided that since the contract specified that certain temperatures would be maintained, proof that this was not done constituted sufficient grounds for recovering damages. The fact that the unit was in perfect mechanical working order did not affect the warranties of performance.

In another case, milk cooling equipment sold to a dairy was warranted to "amply cool milk, reduce cooling expenses by one-half, and take less trouble than ice." Although this clause seems entirely too broad to be relied upon, it formed the basis for the buyer's defense when sued for the balance of the purchase price. Upon proof that the cooler did not fulfill these warranties, the court released him from liability for the unpaid balance. Obviously, all-inclusive promises of this type are unwise because contractors may be forced to abide by overly enthusiastic representations.

While these reported decisions seem to place a strict interpretation upon the promises made by the seller, the omission of specific guarantees of performance is dangerous. In the absence of definite agreements, the courts are likely to find that since the equipment was purchased for a particular purpose, there is an implied warranty that it will be fit for that purpose.

The appellate court of Illinois upheld a judgment last year in favor of a restaurant owner who was sued on a note representing the balance due on an air conditioning installation. The contract of sale contained no guarantee of performance, merely enumerating the items being sold as "One warm air conditioner, one complete set of duct work, all controls for heating and one complete installation for winter air conditioning." The corporation making the sale contended that its sole responsibility was limited to the delivery of these exact items and that according to the uniform sales law, there is no implied warranty of fitness for a particular purpose in a sale of goods by description. Finally, the seller summed up its case by pointing out that in any event, the contract itself provided: "There are no warranties, express or implied, made by either the manufacturer or the seller, other than the manufacturer's standard warranty on its own equipment."

In spite of all these explicit provisions, both the lower court and the appellate court decided that it was unreasonable to assume that all the buyer purchased were separate pieces of equipment. What the contract really called for was the sale of described machinery to function as a unit in "air conditioning" the premises. Since the contract contained no definition of this term and it has not yet acquired a settled legal meaning, the buyer was permitted to introduce oral testimony to show the understanding between the parties. On the basis of evidence that the system did not function in conjunction with the heating apparatus in the defendant's restaurant so as to remove smoke and odors, purify the air and heat the premises, the buyer was released from liability on his note.

In this connection, it is interesting to notice a directly contrary case decided by the Georgia courts. Their view was that a contract for the sale of a specifically described refrigerating plant cannot be modified by oral evidence; that the purchase was of a definite article and the buyer cannot escape liability because the machine did not operate as it was supposed. However, it seems more reasonable to believe that the majority of courts will adopt the attitude taken by the Illinois appellate court.

Consolidated Edison Installs Steam and Condensate Piping

By M. A. Guigou* and S. W. Spielvogel†

The description of the new 24 in. steam and 10 in. condensate lines between the Hudson Ave. and Gold St. stations of the Consolidated Edison Co. of New York is concluded with this discussion of the piping joints and materials, stress relieving, support of indoor piping, insulation, and reducing and desuperheating

A 24 IN. steam line and a 10 in. condensate line between the Hudson Ave. and Gold St. stations of the Consolidated Edison Co. of New York were recently put in service as described in the April HPAC.[3] The outdoor portions of the lines are supported on catenary cables between the two buildings, and there are two intermediate structural steel towers. Support and erection of the outdoor parts of the lines were explained in April; this month, the piping joints and materials, stress relieving, support and insulation of the indoor piping, and the desuperheating installations are discussed.

Piping Joints and Materials—Considerable thought was given to the selection of a suitable and economical type of joint. It was felt that flanged joints in the overhead outdoor run along the bank of the East River would lead to high maintenance cost because non-rigid construction of the line would permit swaying under wind pressure and cause joint leakage. Repair during inclement weather at considerable distance above a busy dock would of necessity run into more than ordinary expenditure for this type of work. It was therefore decided to use welded joints for the 24 in. steam line and the 10 in. condensate return header, with the exception of the terminal connections of these headers to the existing headers in the two stations and the joints for the pressure reducing valves, which were flanged. The flanges for the steam headers are with raised serrated face and conform to the 300 lb ASA standard. Those of the condensate header conform to the 150 lb series of the same standard.

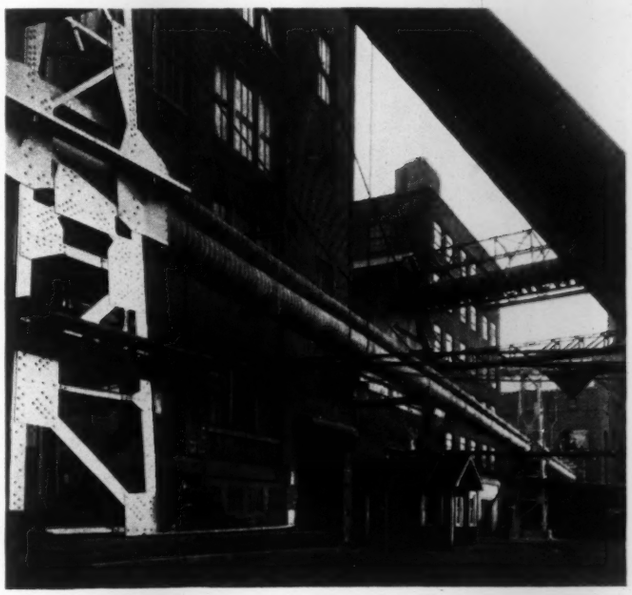
In order to keep the cost of welding to the minimum, the piping material was selected so as to permit the use of the smallest wall thickness at a safety factor of approximately five for the most unfavorable combination of working stresses. Its weldability was assured by limiting the carbon content to a maximum of 0.35 per cent. It was possible to satisfy these demands with a sufficient quantity of readily available Grade B seamless tubing of an ultimate tensile strength of 65,000 lb per sq in., conforming to the ASTM standard specification for lap welded and seamless steel pipe for high temperature service, serial designation A 106-36. The purchase order included the supplementary requirements of this specification in order to insure a good product.

On this basis a ½ in. thick pipe wall was found to satisfy the requirements of the indoor piping and the center portions of the three outdoor spans. The balance of the outdoor piping—the portions in the restraining zones at each side of the two towers and the sections at the inlets to both stations—required a ¾ in. wall thickness.

The joints for the large size lines were made with butt welds using a 45 deg bevel with $\frac{1}{16}$ in. land. As an aid in lining up pipe for welding and in order to prevent weld splatter and the formation of icicles, straight faced carbon steel backing rings 1 in. long and $\frac{3}{16}$ in. thick were used. At the junction of the ½ in. and ¾ in. thick pieces, the backing ring was accommodated by machine boring the ¾ in. pipe wall so as to match the inside diameter of the ½ in. pipe, tapering back gradually to the full wall. Pipe to pipe joints for sizes 1½ in. or smaller were made with fillet welded pipe sleeves, and pipe to valve or fitting joints with fillet welded sockets.

All welding on the steam line was performed by direct current electric arc using covered electrodes, while the field welding of some of the joints on the condensate return line was by gas welding. Preheating of the parts to be welded was not resorted to as the carbon steel material was found to be easily welded.

Fig. 1—View of the outdoor piping



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†Assistant Division Engineer, Consolidated Edison Co. of New York, Inc.

[3]Supporting and Erecting a 24 Inch Steam Tie Line, by M. A. Guigou and S. W. Spielvogel, HEATING, PIPING AND AIR CONDITIONING, April, 1939, pp. 229-231 and 239.

Stress Relieving—Welds on pipe diameters 2½ in. and larger on the steam line, falling under classification A of the ASA code for pressure piping, according to service, were all stress relieved to remove the residual stresses set up by welding. This was accomplished by means of an electric inductance type of heater consisting of flat strip coil collars hinged in two halves and made so that each collar can accommodate three or four pipe sizes.

The collar was clamped over the pipe at the welded joint. In general the welded joints were located away from obstructions or hangers so as to permit placing the center of the collar as near as possible to the center of the weld. Where the collar could not be placed centrally enough over the joint because of unavoidable obstructions or contour changes, a heavy stranded copper wire cable, insulated from the pipe with sheet asbestos, was wrapped around the joint. The turns of this coil were insulated with asbestos rope. Because of its flexibility this latter type of heater proved quite helpful in expediting the work in the field.

Support of Indoor Piping—Satisfactory experience with previous installations determined the use of constant support spring hangers for the indoor piping. Their sensitivity in regard to supporting effort and the ease with which load corrections can be made in case of contingencies arising during construction make this type of hanger a practical means for assuring definite support without inducing pipe stresses due to weight.

Piping below 4 in. in diameter was supported by flat link chain hangers in the manner shown in Fig. 2. Experience with this assembly showed savings through ease of erection and reduced cost in labor and material. These hangers were used for loads up to 500 lb with a safety factor of six for chain, eye bolt and S hook.

Fig. 2—Flat link chain hangers are used for indoor piping of 4 in. diameter and under

Insulation—The indoor portions of the system are insulated with magnesia, except the 24 in. and 16 in. steam lines, which are covered with sponge felted insulation (slightly less thick than that on the outdoor lines) to take advantage of the sectional length feature of this insulating material.

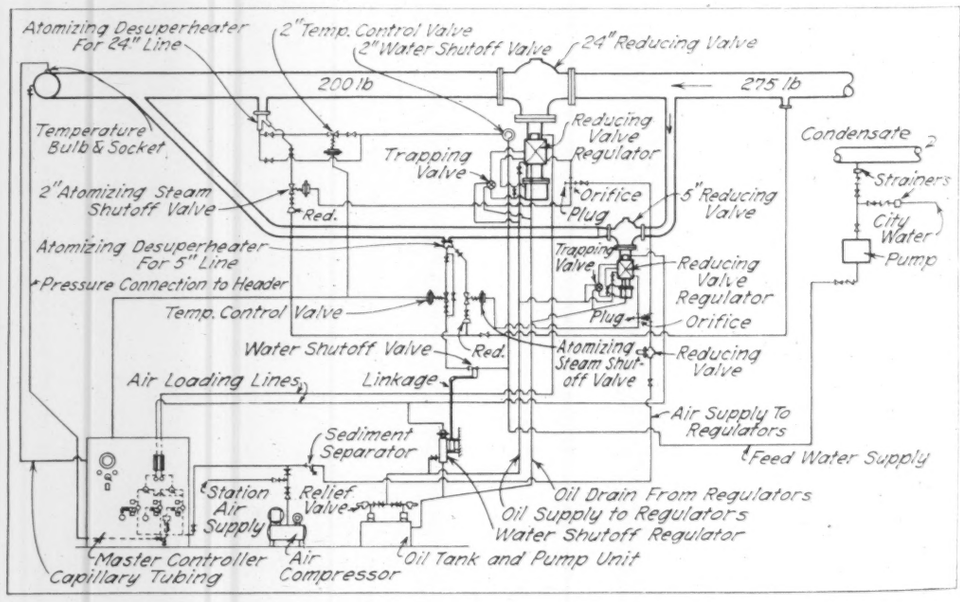
Pressure Reducing and Desuperheating System—In order to conform to the characteristics of the turbines installed in the older Gold St. station it was necessary to reduce the Hudson Ave. station steam pressure from 275 psi (lb per sq in.) to 200 psi and to desuperheat approximately 120 F. A motor operated gate valve was installed at the source of steam supply in the Hudson Ave. station and the reducing and desuperheating equipment is situated in the turbine room of the Gold St. station. (The desuperheater shown in the diagram on page 230 of the April HPAC is not the one referred to here).

Fig. 3 shows the installation for reducing pressure and desuperheating. It will be noted that there are two reducing valves. The 5 in. valve has a capacity of 40,000 lb per hr of steam, sufficient for starting up all auxiliaries in the station, while the 24 in. valve (which, incidentally, weighs 15,000 lb) has a capacity of 900,000 lb per hr. Each of the reducing valves is operated by a double acting hydraulic cylinder, this being an integral part of the valve. The cylinders are operated by oil pressure and controlled by an oil operated regulator.

The valve regulator is in turn controlled by a master loading air pressure received from the master panel. The master controller consists of a steam pressure element which controls an air bleed cup valve so as to change the master loading air pressure whenever the steam pressure changes; the pressure element of the master controller is connected to the main steam line at a location on the low pressure side of the reducing valve.

The reducing valves may be controlled automatically by the steam pressure element or manually from the control panel. They may also be controlled by hand, using the handwheel mechanism on the valve stem. The two valves may be operated separately or at the same time, or one may be placed on automatic control while the other is on manual control.

Fig. 3—Pressure reducing and desuperheating equipment



Performance of Coils for Dehumidifying Air

By William Goodman*

THE appendices for this series of articles on performance of coils for dehumidifying air are concluded this month. In this series, the author has developed new and simple formulas for computing the final dry and wet bulb temperatures of the air leaving a coil. Particularly noteworthy is the fact that the final wet bulb depression of the air has been shown to depend upon the initial wet bulb depression of the air for both direct expansion and counterflow coils. This makes computation of the final dry bulb temperature the work of a moment.—THE EDITOR.

Appendix 15

Tests on Direct Expansion and Counterflow Water Coils

In order to verify the various formulas in this article, the writer's earlier tests published in the reference of Footnote 1 and a new set of tests on counterflow water coils were analyzed.

Although the earlier tests were run with water, sufficiently large quantities were used to keep the temperature of the water substantially constant as it flowed through the coils. In other words, the conditions were analogous to those in direct expansion coils. For this reason these earlier tests are occasionally referred to as direct expansion tests in order to distinguish them from the new counterflow water coil tests which are also discussed.

The data for the earlier tests are given in detail in the reference of Footnote 1. These earlier tests were analyzed again by means of the new methods presented here. As in the original tests, the film coefficients were determined from the test data on the five row coil, and these data were then used in the formulas in this article to compute the condition of the air leaving coils having from two to seven rows of tubes. The analysis of the new tests gave a value of $f_R = 650$, whereas the analysis of the earlier tests gave $f_R = 632$.† For the air side, the new analysis gave $f_s = 0.365\ V_a^{0.5}$, compared to $f_s = 0.37\ V_a^{0.5}$ from the earlier tests. Considering the fact that different formulas were used in analyzing the data, the agreement seems good.

The computed final dry and wet bulb temperatures for the earlier tests are tabulated in Table B. A comparison with the results tabulated in Table 7 of the reference of Footnote 1 shows that the agreement is excellent. Even more significant is the comparison in Table C. In this table are listed the percentage

*The Trane Co. Member of Board of Consulting and Contributing Editors.

Part 7. Part 1 was published in November, 1938, pp. 697-701 and 707; Part 2 in December, pp. 777-781; Part 3 in January, 1939, pp. 13-19; Part 4 in February, pp. 83-86; Part 5 in March, pp. 157-160; and Part 6 in April, pp. 233-236.

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†See list of symbols, p. 235, April issue.

Table B Computed Final Dry and Wet Bulb Temperatures for Earlier Direct Expansion Coil Tests

Test No.	Rows of Tubes: 2 Dry	2 Wet	3 Dry	3 Wet	4 Dry	4 Wet	5 Dry	5 Wet	6 Dry	6 Wet	7 Dry	7 Wet
16	71.3	63.3	66.9	61.2	63.5	59.4	61.6	57.7	58.4	56.3	56.6	55.1
17	75.1	70.0	71.0	67.3	67.7	65.0	64.8	62.9	62.4	61.0	60.4	59.4
18	75.1	68.2	70.5	65.6	66.9	63.3	63.8	61.2	61.2	59.4	59.1	57.8
19	74.0	65.0	69.2	62.7	65.4	60.7	62.3	58.9	59.8	57.4	57.8	56.0
20	70.5	62.7	65.8	60.4	62.1	58.4	59.3	56.7	57.0	55.2	55.2	54.0
21	65.1	60.4	61.7	58.4	58.9	56.6	56.7	55.1	54.9	53.8	53.5	52.7
22	72.1	65.9	67.4	63.1	63.6	60.6	60.7	58.6	58.2	56.8	56.2	55.2
23	64.3	61.0	60.7	58.5	57.8	56.4	55.6	54.7	54.0	53.4	52.7	52.3
24	67.7	64.1	64.7	62.1	62.0	60.2	60.0	58.7	58.2	57.3	56.8	56.1
25[a]	85.0	68.9	77.9	66.2	72.3	63.9	67.9	61.8	64.3	59.9	61.4	58.2
26[a]	80.0	66.5	71.7	63.0	65.7	60.1	61.3	57.7	58.2	55.8	55.7	54.2

[a] Part of coil surface was dry during these tests. These tests were not used for evaluating film coefficients.

Table C—Table for Earlier Direct Expansion Coil Tests Showing:
1. Percentage deviation between computed total heat lost by air and actual total heat lost by air as obtained by test.
2. Percentage deviation between computed sensible heat lost by air and actual sensible heat lost by air as obtained by test.

Test No.	Rows of Tubes: 2 Sensible Heat	2 Total Heat	3 Sensible Heat	3 Total Heat	4 Sensible Heat	4 Total Heat	5 Sensible Heat	5 Total Heat	6 Sensible Heat	6 Total Heat	7 Sensible Heat	7 Total Heat
16	—8.6%	+1.3%	+0.6%	—8.2%	—3.3%	—0.5%	—2.1%	—0.3%	0%	+2.9%	0%	+2.1%
17	—11.5	+1.9	—2.0	—0.4	—3.7	—2.1	—1.9	+0.9	+1.7	0	+3.7	+0.2
18	—12.8	+0.8	—2.3	—2.9	—4.2	—1.4	—2.5	—0.1	+1.2	—0.6	+1.8	+0.4
19	—8.2	—1.0	—1.1	—1.0	—2.6	—0.6	—1.6	+0.7	+0.7	—2.3	+1.7	+0.7
20	—10.6	—2.7	—3.6	—3.8	—4.6	—1.4	—3.0	—0.5	—0.7	—3.9	+1.4	—1.7
21	—10.6	+2.0	+0.7	—2.0	—2.4	+1.2	—0.5	+1.2	+3.0	—0.5	+4.3	+2.1
22	—4.9	+4.8	+2.8	+7.4	0	+5.0	+0.8	+1.5	+3.8	+3.5	+5.0	+2.3
23	—3.4	—0.6	+0.7	+3.1	+0.6	+1.5	+2.0	—0.8	+2.8	+0.8	+5.5	+2.4
24	—6.8	0	+1.8	+4.9	—1.4	+1.8	0	—1.3	+3.5	+1.0	+2.7	—0.3
25[a]	—7.0	—9.3	—2.8	—5.2	—5.8	—5.6	—3.5	—3.4	—1.9	—4.1	—0.4	—2.5
26[a]	—8.6	—7.2	—1.1	—6.6	—2.3	—3.2	—1.3	—1.4	—0.2	—3.0	+1.4	—0.6
Average Deviation	0% / —8.5	+2.2% / —4.2	+1.3% / —2.2	+5.1% / —3.8	+0.6% / —3.4	+2.4% / —2.1	+1.4% / —2.1	+1.1% / —1.1	+2.4% / —0.9	+2.1% / —2.4	+3.1% / —0.4	+1.5% / —1.3

Average of all sensible heat deviations { +1.8%, —2.9 } Average of all total heat deviations { +2.4% / —2.5 }

[a] Part of coil surface was dry during these tests. These tests were not used for evaluating film coefficients.

deviations of the computed total heat removed from the actual total heat removed as obtained by test. Also listed are the deviations of the computed sensible heat from the actual sensible heat as measured during the test. In general, the percentage deviation is small except for a few erratic points. The worst deviations occur in the second row. The reason is that the temperature drop of the air through a two row coil is relatively

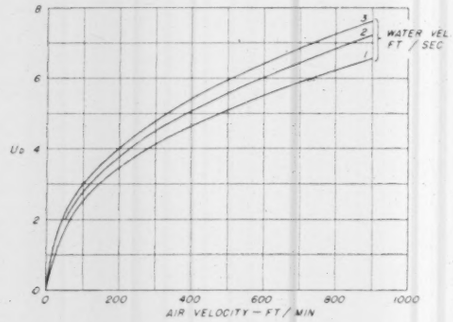

Fig. 18—Values of U_D for various air and water velocities obtained by test of the six row counterflow coil discussed in Appendix 15

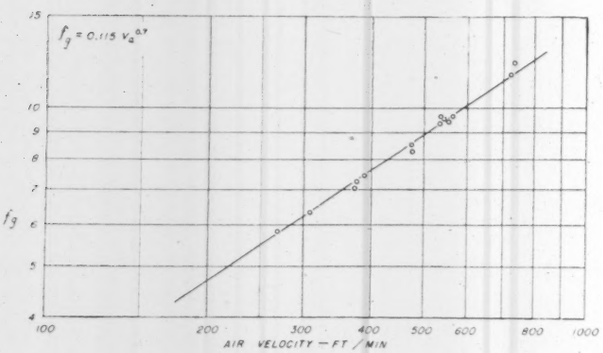

Fig. 19—Air film coefficients for various air velocities obtained by test of the six row counterflow coil discussed in Appendix 15

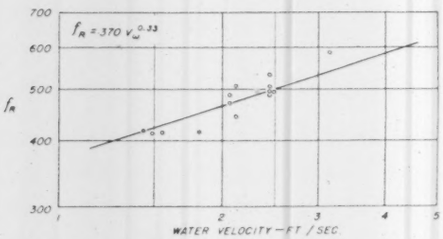

Fig. 20—Water film coefficients for various water velocities obtained by test of the six row counterflow coil discussed in Appendix 15

small. Hence, any small error in the temperature measurements is magnified out of all proportion when computing the percentage deviations. For this same reason the results on the one row coil were omitted.

For all of these earlier tests, the average deviation in the computed total heat is +2.4 per cent and —2.5 per cent. For the sensible heat the averages are +1.8 per cent and —2.9 per cent.

In order to verify the equations for counterflow water coils, two coils were tested, a four row and a six row. The physical data of these coils are listed in Table D. All of the dry surface tests were run on the six row coil. The values of U_D obtained are plotted in Fig. 18.

Wet surface tests were run on both the four row and the six row coils. The measurements of temperature, and the measurements of air and water obtained from these tests are given in Table E. The data in Tables D and E, together with Figs. 18, 19 and 20 are sufficient to permit analyzing all of the tests. The film coefficients for these coils were obtained from the test data on the wet six row coil. The values of U_D needed were read from Fig. 18. The results of these analyses for the film coefficients are plotted in Figs. 19 and 20.

Table D—Physical Data of Coils Used in Counterflow Water Tests

1. Face dimensions of coil	12 in. x 24¾ in.
2. Face area of coil	2.02 sq ft
3. Diameter of tubes	½ in. OD
4. Internal cross-sectional area of tubes	0.152 sq in.
5. Number of tubes through which water is distributed	13
6. Area of external cooling surface per sq ft of face area per row of tubes	20.07 sq ft
7. Area of internal cooling surface per sq ft of face area per row of tubes	0.859 sq ft
8. Ratio of external to internal area	30.3
9. Number of fins per foot	85
10. Type of fins	flat plate aluminum
11. Staggered copper tubes	
12. Spirals inside of all tubes	

Table E—Test Data on Six Row and Four Row Counterflow Coils

Six Row Coil

Test No.	t_1	t'_1	t_2	t'_2	t_{R1}	t_{R2}	G	G_a
1	88.4	76.8	68.9	67.6	55.7	61.7	6550	8075
2	88.8	78.5	67.9	67.0	55.7	61.5	5124	8075
3	89.2	79.0	65.4	64.6	55.6	60.7	3525	8700
4	90.2	77.7	62.0	61.4	55.5	59.3	2440	8300
5	90.8	79.3	64.7	64.0	54.5	60.5	3384	7925
6	91.3	79.8	63.6	62.9	54.3	58.8	3410	11220
7	90.1	79.5	66.8	65.9	54.1	61.0	4325	7335
8	90.6	79.9	68.2	67.5	54.4	63.3	4300	5270
9	92.3	80.1	69.5	68.5	54.3	63.6	4943	5520
10	92.1	79.9	68.3	67.4	54.1	61.7	5045	7405
11	88.3	77.3	69.0	67.8	54.0	61.5	6673	7580
12	90.1	78.5	63.5	62.9	53.4	60.8	2797	5060
13	89.6	78.4	69.3	68.3	56.7	63.7	4870	6420
14	88.3	76.9	67.0	65.9	55.9	61.1	4850	8820

Four Row Coil

Test No.	t_1	t'_1	t_2	t'_2	t_{R1}	t_{R2}	G	G_a
15	90.0	79.5	70.3	68.8	54.7	62.8	2820	3300
16	89.4	78.6	68.0	67.0	55.0	60.5	2820	5250
17	91.5	80.6	68.9	67.4	55.0	60.0	2800	6770
18	88.3	76.9	74.7	72.0	56.7	66.2	5980	2800
19	87.9	77.0	71.2	69.4	55.9	62.7	4285	4162
20	89.1	76.2	69.1	67.1	55.4	59.5	4285	7670
21	89.9	79.2	75.5	73.4	57.4	64.9	6065	4450
22	89.5	78.3	73.4	71.3	55.8	61.6	6060	6720
23	89.6	78.5	72.8	70.8	55.5	60.4	6130	8820
24	89.9	76.7	71.0	69.2	59.1	63.1	3948	6180
25	94.0	83.1	76.6	74.8	57.6	64.2	4940	6430
26	89.2	77.3	72.0	70.1	57.2	62.0	4960	6545
27	89.7	77.8	73.8	71.8	57.8	65.0	4970	3708
28	90.2	78.4	71.6	69.8	56.5	60.5	4970	9490

Table F—Computed Final Dry and Wet Bulb Temperatures for Counterflow Coils

Six Row Coil			Four Row Coil		
Test No.	Dry	Wet	Test No.	Dry	Wet
1	68.7	67.5	15	70.3	68.9
2	67.9	67.0	16	68.7	67.2
3	65.3	64.7	17	69.2	67.7
4	62.4	61.8	18	74.3	72.0
5	64.9	64.2	19	71.4	69.5
6	64.0	63.3	20	69.7	67.5
7	66.8	66.0	21	75.4	73.5
8	68.2	67.4	22	73.5	71.5
9	69.4	68.4	23	73.0	70.7
10	68.4	67.4	24	71.6	69.4
11	68.7	67.6	25	76.3	74.3
12	63.5	62.9	26	72.2	70.0
13	68.9	68.0	27	73.9	71.7
14	66.8	65.9	28	72.0	69.8

The film coefficients were then read from the curves in Figs. 19 and 20, and the final condition of the air leaving the four row and six row coils was then computed for the different tests listed in Table E by the counterflow equations. The results of these computations are listed in Table F. A comparison of the computed final dry and wet bulb temperatures in Table F with the final temperatures in Table E which were obtained by test shows that the agreement is good. This can also be verified by referring to Table G, which shows the percentage deviations between the computed total and sensible heat removed, and the actual sensible and total heat removed as obtained by test. In general, the deviation is quite small. As can be seen in Table G, the average deviation of both coils is less than ± 2 per cent for both the sensible and total heat removed. It is not surprising that the results of the six row coil are so good because the analysis of the film coefficients was based on this six row coil. However, the comparison between the computed and test results of the four row coil is equally good in spite of the fact that an entirely different set of tests was run on the four row coil, and that these tests were not used to determine the film coefficients.

Judging from the results of the earlier tests of Footnote 1, and from the results of these counterflow water tests, it is quite evident that the equations and methods presented here can be used accurately to predict the performance of both direct expansion and counterflow water coils.

A word as to the test set-up for the counterflow water coils is desirable. The set-up shown in Fig. 17 was developed after these tests were run. During the water tests, dry surface was avoided by humidifying the air so that its initial dew point was quite high. This method is not as satisfactory or as accurate as the use of a tell-tale coil (see p. 84, February issue).

In order to make the results of these tests comparable with those of earlier tests, the value $c = 0.24$ was used, and also Goodenough's tables of the properties of air (see 1935 ASHVE *Guide*). This required that values of a be computed from Goodenough's table. The values of a listed in Table H were computed in the manner described in Appendix 4, and were then used, together with Goodenough's table, in analyzing the tests. If the true enthalpy had been used in computations, it would have made little difference which table of the properties of air was used. For a further discussion of this point, see the reference of Footnote 3.

Table G—Table for Counterflow Coil Showing:
1. **Percentage deviation between computed *total* heat lost by air and actual *total* heat lost by air as obtained by test.**
2. **Percentage deviation between computed *sensible* heat lost by air and actual *sensible* heat lost by air as obtained by test.**

Six Row Coil			Four Row Coil		
Test No.	Sensible Heat	Total Heat	Test No.	Sensible Heat	Total Heat
1	+ 1.0%	0 %	15	0 %	+ 0.2%
2	0	+ 0.7	16	— 3.3	— 2.4
3	+ 0.4	— 1.7	17	— 1.3	— 3.2
4	— 1.4	— 2.9	18	+ 2.9	— 0.7
5	— 0.8	— 2.5	19	— 1.2	— 1.0
6	— 1.4	— 3.6	20	— 3.0	— 1.9
7	0	— 0.1	21	+ 0.7	+ 3.1
8	0	+ 1.1	22	— 0.6	+ 1.2
9	+ 0.4	+ 1.2	23	— 1.2	+ 0.1
10	— 0.4	+ 0.1	24	— 3.2	— 0.9
11	+ 1.6	+ 0.3	25	+ 1.7	+ 3.6
12	0	— 1.7	26	— 1.2	+ 1.3
13	+ 2.0	+ 0.9	27	— 0.6	+ 2.0
14	+ 0.9	— 0.6	28	— 2.2	+ 0.4
Average Deviation	+ 1.1% — 1.0	+ 0.8% — 1.9	Average Deviation	+ 1.8% — 1.8	+ 1.5% — 1.7

Table H Values of a Computed from Goodenough's Tables, and Used in Analyzing Results of Tests

t	a
47	0.571
48	0.581
49	0.593
53	0.629
54	0.639
55	0.648
56	0.658
57	0.669
58	0.679
59	0.689
60	0.700

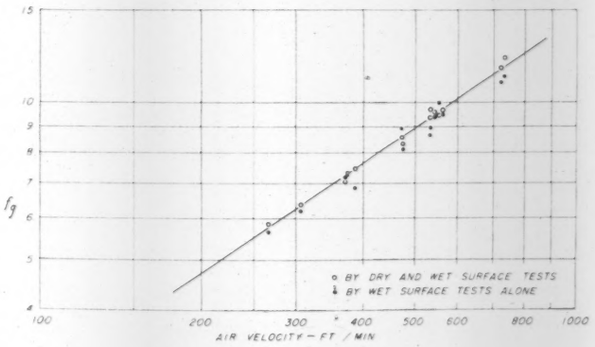

Fig. 21—Air film coefficients of the six row counterflow water coil as determined by tests on dry and wet surface, and by tests on wet surface alone

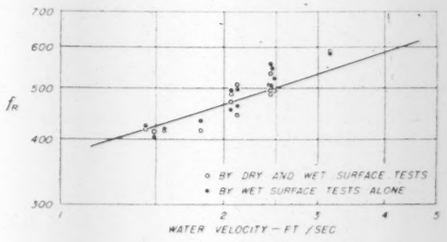

Fig. 22—Water film coefficients of the six row counterflow water coil as determined by tests on both dry and wet surface, and by tests on wet surface alone

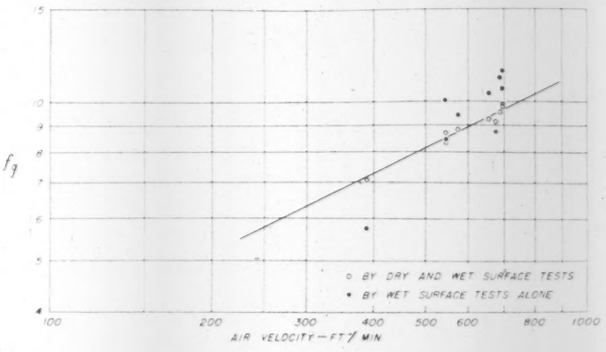

Fig. 23—Air film coefficients for the direct expansion coils as determined by tests on both dry and wet surface, and by tests on wet surface alone

In the tests discussed in the preceding paragraphs, the coefficients were evaluated by means of tests on both dry and wet surfaces. In order to compare the results obtained when the coefficients are evaluated by means of wet surface tests alone, and using Equations 8 and 3 of the text, Figs. 21 and 22 were prepared. These figures are the same as Figs. 19 and 20 except that the film coefficients computed by means of the wet surface tests alone are also shown. As is evident from Figs. 21 and 22, the results obtained by means of wet surface tests alone are not as accurate as the results obtained by both dry and wet surface tests, although they compare favorably with them.

The direct expansion tests of Footnote 1 were also analyzed

by means of the wet surface tests alone. The results obtained for f_s are shown in Fig. 23, with the results obtained by means of both dry and wet surface tests. The points obtained by means of the dry surface tests alone scatter considerably more than the points obtained by means of both the dry and wet surface tests. The value of f_n obtained by means of the dry surface tests alone is 651, whereas the value obtained by means of both dry and wet surface tests is 650. This is a remarkably close agreement. However, the individual coefficients from which the average value of 651 was computed deviated considerably more than the individual coefficients obtained by both dry and wet surface tests.

In both the direct expansion and counterflow tests, there is more scattering of the points computed by means of the wet surface tests alone. For this reason, more accurate results are likely to be obtained by using dry surface tests as well as wet surface tests, although for quick work the results obtained by wet surface tests alone will frequently be sufficiently accurate for many practical purposes.

[*Concluded*]

Air Conditioning Valuable to Public Health

THAT air conditioning is making increasingly valuable contributions toward improving the nation's health is the conclusion of Dr. Albert G. Young, medical director of the Corey Hill hospital at Brookline, Mass. Dr. Young reported his findings to the Edison Electric Institute in an address before the institute's recent sales conference.

In support of his findings, Dr. Young pointed to the success of the Infants' hospital in Boston in lowering the mortality of premature infants from 28.9 per cent to 0.7 per cent by air conditioning the nursery. Likewise, at Corey Hill hospital, post-operative pneumonia has been reduced to 0.1 of 1 per cent, whereas the national average is between 6 and 7 per cent. Moreover, post-operative mortality at the same hospital is only 1.2 per cent, compared to an average of approximately 4.5 per cent in hospitals without air conditioning.

The broader field for improvement of public health, he believes, is through air conditioning of schools, offices and homes. "We can survive for weeks without food, and for days without water, but we can survive only a few minutes without air," Dr. Young pointed out. "Since we are surrounded by and live in the air we breathe we must accept what comes to us, whether it be scented by the flowers of a nearby garden or from the local fertilizer plant. The outdoor air will purify itself, given sufficient time, but if we are to exert any important effect upon it we must do so by preventing its contamination."

The problem of air pollution in urban communities, Dr. Young declared, has become a major factor in public health. It is being attacked from two points—prevention of air pollution by factories, and cleaning the air before it is brought indoors. As most of the urban population spends more than 60 per cent of its time indoors, it is evident that proper cleaning is a constructive procedure.

As evidence of the dangers of air pollution, Dr. Young quoted studies by recognized scientists. It is estimated, he said, that 5 per cent of coal goes into the air as unburned carbon. As affecting health, the quantity of silicate particles and sulphur compound gases in the air are most important. One industrial plant in Chicago, he reported, emits 500 tons of sulphuric acid into the air every 24 hours.

The health department of Chicago, Dr. Young stated, has discovered that in certain areas of the city the dust fall amounted to 460 tons per square mile in January. Comparable findings have been made in St. Louis, Pittsburgh and other industrial cities.

"These facts alone," Dr. Young declared, "are sufficient to justify the conclusion that the outdoor air in urban centers is not 'fresh air.' When such air is brought indoors it is further contaminated by food and body odors. This condition is not conducive to good mental or physical health.

"The air is the chief media through which we regulate body temperature," Dr. Young continued. "Control of humidity is most important to heat regulation. Thus it is evident that summer comfort cooling, properly used, is a good health measure.

"During heat waves the death rate increases fourfold, according to the U. S. public health service. About one-fourth of the deaths are due to heat stroke, the rest to heart disease, cerebral hemorrhage, kidney disease and pneumonia. This is further evidence of the increased load placed on the heart and lowered body resistance during high temperatures.

"By controlling the humidity and temperature of the air through air conditioning, it is possible to provide the best effective temperature so that the individual can perform physical and mental work with great efficiency and less fatigue."

Dr. Young quoted a recent survey of employers using air conditioning, in which 95 per cent reported that air conditioning increased efficiency in offices and factories; 93 per cent found that it decreased fatigue, and 77 per cent found that employees did more work under air conditioning.

The elimination of noise is another contribution to health which Dr. Young lists to air conditioning's credit. "Air conditioning supplies proper ventilation without opening the windows, and is most effective when double windows are used; consequently about 90 per cent of outdoor noise can be excluded," he said. "The constant clamor of city noise constitutes a serious hardship on our nervous system, which leads to impaired hearing, neuroses, loss of sleep, excessive fatigue, and emotional disturbances that jeopardize the complete well-being of most people." By reducing the noise level, it has been found possible to increase the average efficiency of piece work employees in a large insurance office by 8.8 per cent, while typing errors were reduced 29 per cent, machine operators' errors were cut 52 per cent, and employee turnover was decreased 47 per cent, he reported.

Dr. Young predicted that in the near future air conditioning will receive as careful attention in the design and specifications of new buildings as plumbing equipment does today.

Heating · Piping · Air Conditioning

AMERICAN SOCIETY of HEATING and VENTILATING ENGINEERS

Journal Section

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BULLETIN BOARD

The Society has 27 local chapters of which 24 are in the United States and 3 are in Canada. North Carolina Chapter held its charter meeting in Greensboro April 21 and received congratulatory messages from many Society and Chapter officers. New Orleans members are now planning to file a petition for a charter to organize a local chapter in that city.

* * *

A meeting of the Executive Committee of the Committee on Research was held at the Headquarters Office of the Society April 19 to study the progress of the program under way and to plan for future research activities.

* * *

Announcement of the Sixth International Heating and Ventilating Exposition to be held in Lakeside Hall, Cleveland, Ohio, January 22-26, 1940, has just been made. Exhibitors in previous expositions have already taken over 50 per cent of the available space.

* * *

MAKE YOUR PLANS FOR THE MACKINAC MEETING

See p. 338 for more details.

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Small Stokers

By Paul A. Mulcey,* Primos, Pa., and Ralph A. Sherman,**

Columbus, Ohio (*MEMBERS*)

Part 1. Domestic Anthracite Burners

ONE of the few industries which has shown a definite upward trend during the past eight years is that of domestic anthracite burner production. Starting from very humble beginnings, there were only a few large companies manufacturing stokers prior to 1930, and the number of units sold was small. In 1936 anthracite stoker sales amounted to 5,000 units. This figure was doubled in 1937, and is expected to be tripled in 1938. For the first eleven months of 1938 the industry was 42 per cent ahead of the same period in 1937.

Accompanying the accelerating burner output, there has been a definite trend toward lower prices. As a matter of fact, the domestic anthracite stoker is now in a position to compete with other automatic fuel burners. The probabilities are that as time goes on more and more anthracite stokers of increasingly simplified design, and hence lower first cost, will gradually find usage in those territories which up to the present time have been considered as the exclusive market of competitive fuels.

The purpose of this paper is to discuss the general mechanical aspects of small anthracite stokers with particular emphasis on those parts of the mechanism which are peculiar to the burning of hard coal; likewise, to attempt to draw a picture of the present state of development of stokers.[1, 2, 3, 4]

General Principles of Design

The domestic anthracite stoker may be divided into five main component parts. These are:

1. Coal conveyor system.
2. Ash conveyor system (omitted in certain types of stokers).
3. Fan and air distribution system.
4. Combustion retort, at which point the foregoing converge.
5. Drive mechanism.

Fig. 1 shows in cross-section how these five parts are correlated.

Items 1 and 4 are those which present the greatest problems to designers, and which will be considered in some detail in this paper. The ash conveyor, although an important part of many anthracite stokers, does not present any important obstacle, nor is its design particularly critical. The problems involved are those of materials handling, mechanical layout, and noise elimination. The removal of anthracite ashes either by gravity to pits or mechanically is fortunately one of the minor items in stoker design.

The supply of air in an anthracite stoker is a problem which may be treated from a general knowledge of the subject of fans and ducts. No special volume regulators

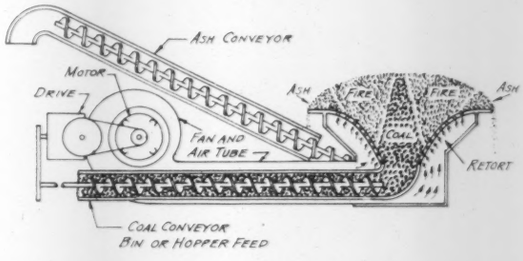

Fig. 1—Component parts of typical anthracite burner

or pressure compensators are required, since combustion in a well designed anthracite retort is uniform. Under the subject of retorts the problem of air distribution in the fire will be discussed a little more fully.

Many types of drive are used in anthracite burners. However, the essential elements consist of a motor which turns the fan impeller either directly or through pulleys and at the same time moves the coal and ash conveyors by means of a speed reduction element. The latter may be of the gear or hydraulic type. Under normal conditions the fan consumes the greatest portion of energy supplied to the stoker unit as the remainder of the mechanism requires only a small amount of power.

Detailed design of the retort will be considered later. However, mention of the mechanical means sometimes used to expedite the removal of ash from the retort may be necessary. Mechanical *agitation* is generally divided into two types: (*a*) that caused by a vertical scraper arm rotating about the retort or other moving pieces serving the same purpose; and (*b*) that caused by rotation of the retort itself. Obviously, mechanical agitation permits the use of smaller clearance between the retort and side walls of the furnace than is required in the *spillover* type of stoker in which the ash falls off by its own weight.

While the drive is an extremely important part of the stoker, it need not necessarily be different in design and layout for an anthracite burner than for a soft coal stoker.

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[1]Domestic Burners for Pennsylvania Anthracite. (*National Bureau of Standards*, CS48-34, 1934).

[2]Performance Expectancy of Domestic Underfeed Stokers for Anthracite, by Allen J. Johnson. (Technical Publication No. 608, *AIM & ME*, 1935).

[3]Small Underfeed Single Retort Stokers, by B. M. Guthrie. (*Transactions ASME*, 1938, Vol. 60, No. 1).

[4]Domestic Anthracite Stokers, by Paul A. Mulcey. (*Transactions* First Annual Anthracite Conference of Lehigh University, 1938).

Presented at the 45th Annual Meeting of the American Society of Heating and Ventilating Engineers, Pittsburgh, Pa., January, 1939.

Types of Anthracite Stokers Available

In order to indicate the relation between the retort and coal conveyor, Fig. 2 shows schematically the four types of bin feed stokers and the hopper type. The latter is rapidly being supplanted by the more convenient bin feed stoker which completely eliminates the manual handling of coal. The first unit shown is the straight

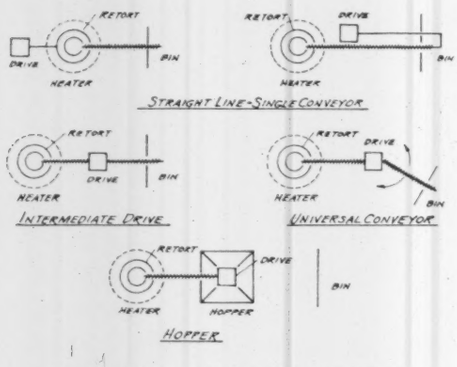

Fig. 2—Various methods of coal feed

line burner with a single conveyor feeding directly from the bin. This type ordinarily has its drive unit and fan on the opposite side of the heater from the bin, although in the case of a plunger type stoker it may be located on the same side. The second burner is also a single conveyor, straight line machine, but the coal conveyor is driven through a shaft and sprocket from the bin end of the conveyor. The third is the straight line, intermediate drive type with the drive mechanism located between the two conveyors. To balance the slight complication of two conveyors, this unit is somewhat more compact. This stoker can also be considered a special case of the *universal* type. The latter stoker permits the bringing of coal from a bin located at any point within a reasonable distance from the furnace, since the conveyor joining the bin and mechanism may be swung at any angle. Finally, the hopper type stoker is, of course, the simplest and is in effect a small version of the straight line bin feed of type 2.

Anthracite Conveyors

In the design of conveyors to transfer anthracite from a hopper or bin to the burning retort, the factors to be considered come under the two general headings of mechanical and chemical (corrosion resistance) considerations. The system must be so designed as to eliminate excessive congestion and at the same time materials must be selected which will withstand the corrosive action of vapors which may be released at certain points in the conveyor. In addition to this, every effort must be made to minimize the concentration of such vapors.

Details of design have been specified by a number of manufacturers. Long trial periods were necessary before any stoker was definitely considered satisfactory. Obviously, therefore, a rather wide variation in coal conveyor design is found both from the mechanical and materials standpoint. For example, conveyor tubes vary in inside diameter from 2 to 4 in. while being constructed of such divergent materials as wrought iron and brass.

A systematic survey of coal conveyors will be made by starting at the bin end of such a unit and following it through to the retort. The inlet end, particularly in the case of models feeding from the bin, is very often so designed as to feed coal into the tube at such a rate as to preclude the possibility of loading the conveyor to capacity. The principal methods of accomplishing this are by having a length of screw extending from the conveyor tube into the bin and having, (*a*) a smaller diameter; (*b*) decreased pitch; (*c*) larger shaft diameter; or (*d*) intermittent screw flights. Another method is to so modify the entrance to the tube as to restrict the flow. The latter has the disadvantage of causing increased breakage of the coal, although by proper design this may be offset by the advantage of preventing the entrance of oversize coal or foreign material which might jam the mechanism. As contrasted with bituminous stoker practice, the use of *crushers* at the intake is to be avoided. American anthracite is so prepared that each size marketed varies within well defined limits. The small amount of accidental oversize encountered is not enough to warrant the use of mechanisms which by their very nature increase breakage and reduce combustion efficiency. On the other hand, the design of bin conveyors to provide readily accessible cleanouts for the removal of large coal and foreign material is highly recommended.

In feeding coal from a bin a desirable feature is to have a relatively large *active* area which will be served by the conveyor. In other words, the dead space from which coal must be moved manually to the conveyor must not be excessive. For this reason many bin feed stokers have relatively long open screws, either with a bearing at the end or floating in the coal. One conveyor of the latter type is made to bring coal in from a fairly large area by extending the screw flights about 40 in. beyond the end of the shaft, thus providing a relatively flexible feeder.

Manufacturers often recommend that bins be constructed with a *hopper* bottom in order that all of the coal will feed by gravity to the conveyor inlet. However, the author believes that a certain amount of dead storage volume is quite desirable to take care of emergencies arising when the coal bin is supposedly empty and a fresh supply of fuel is not readily available.

About 50 per cent of anthracite stoker conveyors have a theoretical feeding capacity equal to that of the portion of the conveyor extending into the bin. The remainder increase in theoretical capacity over a range of 36 per cent to 260 per cent, thus reducing the danger of congestion and excessive breakage. When the universal or intermediate drive type of conveyor is used, the second conveyor undergoes a similar increase in capacity by changing either the diameter or the pitch of the flights or rotating the shaft at a slightly greater speed.

A point very often considered of vital importance is the relation between conveyor dimensions and breakage of the coal. Excessive degradation, because of its adverse effect upon combustion, is undesirable and should be eliminated wherever it is encountered. In order to insure the free and even flow of hard coal through a screw conveyor it is essential that all surfaces be smooth.

free from all unnecessary projections, and that there be no constriction of cross-section or obstacle which might cause congestion. The experience of a number of designers indicates that screw flights should possess square edges in order to obviate any wedging of particles between the worm and tube walls.

In cases of bin conveyors having screws with identical dimensions both in the conveyor tube and extending into the bin, the danger of overfeeding is sometimes acute due to the fact that the capacity of the extension worm is greater than that of the conveyor itself. Under such conditions congestion at the inlet, excessive degradation, and possibly complete mechanical stoppage of the conveyor may result. The tendency to overfeed is influenced by the length of exposed screw and the relation between flight dimensions and coal size. The experiment given illustrates this point.

A bin feed conveyor having a 2½ in. inside diameter steel tube and fabricated screw with 1⅞ in. diameter and pitch was installed at an angle of 22 deg to the horizontal. The worm was allowed to project various distances, and after each change 500 lb of coal were conveyed. The accompanying table gives the results obtained:

Projection (In.)	Size Coal	Degradation Per Cent	Operation
15	Buckwheat	6.0	Overfeeding
10	Buckwheat	2.4	Slight Overfeeding
5	Buckwheat	1.0	No Overfeeding
15	Rice	2.0	No Overfeeding
10	Rice	1.2	No Overfeeding
5	Rice	0.8	No Overfeeding

This experimental work is obviously applicable only to the conveyor described, but from it can be drawn the general conclusion that where no special pick-up worm is used, the length of exposed flights must be maintained at a minimum.

Although the clearance between conveyor screw and tube is often considered as a major factor in degradation, an actual survey has shown that this is not necessarily true. For example, clearances in the conveyors of stokers approved by Anthracite Industries, Inc. vary from 7 per cent to 50 per cent of the screw diameter. In conveyors with clearances ranging from $^{3}/_{64}$ in. to $^{5}/_{8}$ in. degradation of buckwheat size anthracite has been found to be reasonably limited. On the other hand, the fact that clearance is a contributing factor is shown by the following experiments in which all other factors were held constant:

Experiment No. 1: Bronze coal tube 2⅛ in. inside diameter stainless steel fabricated worm 2⅛ in. outside diameter. By using a smaller tube clearance was reduced from 0.25 in. to 0.047 in. This resulted in a 20 per cent reduction in the amount of undersize formed.

Experiment No. 2: In this case a cast-iron tube 3½ in. inside diameter was used in conjunction with two cast steel worms of approximately the same proportion but different diameters. By increasing clearance from 0.125 in. to 0.344 in., 34.6 per cent of the breakage was eliminated.

In these experiments buckwheat size anthracite screened between 0.312 in. and 0.562 in. diameter round mesh was used. The coal had identical characteristics in each case.

Although lacking in completeness, the foregoing evidence indicates a tendency toward maximum degradation at a point between zero clearance and clearance equal to the size of particles being moved. This maximum point is probably that at which there is the greatest tendency for wedging of coal between the conveyor flight and tube walls. Further study of this problem will be well worth the effort to the stoker industry.

Table 1—Approximate Limits in Dimensions of Small Anthracite Screw Conveyors

	Tube I.D. In.	Screw O.D. In.	Ratio Diameter/Pitch	Clearance In.	RPM	Flight Thickness In.	Shaft Diameter In.
Maximum	4	3⅞	1.23	⅝	9.5	⅜	1⅛
Minimum	2	1	0.5	1/16	1.2	3/32	½

The effect of conveyor speed is indicated in Fig. 3. A 3½ in. inside diameter wrought iron tube with a $2^{13}/_{16}$ in. outside diameter cast steel screw having a pitch of 2½ in. was allowed to feed 23 lb per hour at various speeds of rotation. This was accomplished by the use of a bin conveyor which was operated at constant feed. Over the range explored variation of the speed of rotation even up to 100 per cent resulted in no appreciable change in degradation. The rate of rotation of anthracite screw conveyors at rating varies from 1.2 to 9.5 rpm. Table 1 shows approximately the limits ordinarily encountered in the dimensions of small anthracite screw conveyors.

Conveyor Materials

There is a marked tendency toward the use of corrosion resistant steel shafts and flights in anthracite conveyors, particularly at the retort end. It has been definitely shown that chemical action rather than mechanical abrasion is responsible for the major part of conveyor deterioration. Experience indicates that it is the draft and temperature conditions in the conveyor rather than the number of tons of coal conveyed which determine its life.

Moisture adhering to the surface of anthracite often contains small amounts of dissolved sulphur compounds which may under certain conditions cause corrosion of metals. When coal passes through the conveyor toward the retort it may encounter the following conditions: (*a*) sufficiently high temperatures to vaporize both the water and acids adhering to the surface of the coal: (*b*) draft conditions which allow the concentration of these vapors to build up by preventing (or retarding) their escape into the retort; (*c*) in some cases draft conditions may be such as to actually force corrosive vapors back from the retort.

Corrosion is encountered when conveyors are allowed to remain filled with coal during long periods of shut-

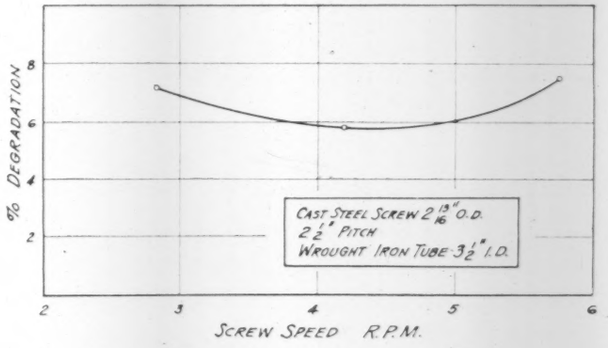

Fig. 3—Effect of worm speed on degradation

down such as during the summer months. Worms operating all year around very often outlast those which are not used during the summer.

From the foregoing it is obvious that the remedy for most of the stoker conveyor corrosion lies in: (*a*) the use of acid resisting materials; and (*b*) modification of design to cause the dilution and rapid expulsion of vapors from the conveyor tube. A combination of the two is very often used, since it is widely recognized that, aside from corrosion, *gassing back* at the hopper or bin is a source of annoyance to the consumer.

The simplest and most universally used method for the sweeping of vapor from the conveyor consists of a connection or *cross-over* between the air duct and conveyor tube in such a manner as to impose the necessary amount of air pressure upon the latter to cause a continous flow of air into the retort. Provision must be made at the same time to limit the amount of air which flows back toward the bin to a minimum. This is accomplished by intentionally causing a temporary congestion of coal so as to form a plug at a point between the conveyor inlet and the air cross-over.

A survey of the manufacturers of approved anthracite stokers gives an interesting insight into the various materials used in coal conveyors. For example, approximately 45 per cent of the manufacturers use fabricated steel worms, while 30 per cent use fabricated corrosion resistant steel (usually approximately 20 per cent chromium), and the remaining 25 per cent, cast steel. The distribution of materials used in coal tubes on the other hand is approximately

Wrought Iron	45 per cent (includes steel pipe)
Cast Iron	30 per cent
Bronze	25 per cent

In many cases several of these materials are used in the same stoker. For example, in a bin feed conveyor the major portion of the tube outside the furnace may be wrought iron pipe, with that part extending into the furnace of bronze. Likewise a fabricated worm may be constructed of ordinary steel with that portion within the furnace being of chromium steel. The advantage of this latter procedure is readily recognized when it is realized that the formation of vapor in coal conveyors may be greatly reduced, but can rarely be completely eliminated.

Many other materials have been used experimentally for coal screws. Some, such as monel metal and bronze, have been found to resist corrosion but to be subject to abrasion. Others (stellite, tantalum, and vanadium steel) are at present too expensive. Difficulty due to warpage of cast iron has prevented extensive work with this metal. Manganese steel and Swedish steel were found to be subject to excessive wear. Plated and otherwise metal-surfaced screws have thus far been inferior to ordinary steel. Finally, several experimenters have tried vitreous enamel with success as far as corrosion and abrasion are concerned, but mechanical difficulties resulted in cracking and chipping.

It is of interest to note that the majority of anthracite conveyor screws are constructed of fabricated steels. The advantages claimed are: *a*. Greater accuracy obtainable. *b*. Square outer edges. *c*. Less wear at edge. *d*. No fillets necessary. *e*. Greater ease in splicing.

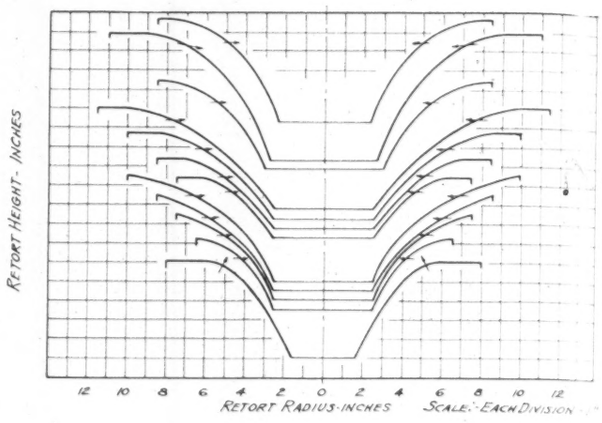

Fig. 4—Typical retort contours

The development of improved methods of production is also exerting an influence in favor of fabricated screws. Greater structural strength is now possible by processes which wrap the flight onto the shaft in such a manner as to grip the latter tightly and uniformly at all points.

A conveyor not previously mentioned because its use is somewhat restricted is the plunger type. It is, however, being used very successfully in one well known anthracite burner both for hopper and bin feed. The plunger, when viewed from above, resembles a series of contiguous truncated cones having a common axis, while from the side it has a saw tooth profile.

Anthracite Burner Retorts

The combustion performance of an anthracite stoker is largely dependent upon the design and construction of its retort. The shape of the latter is highly important because of its relation to air distribution and the shape of the burning zone. The method of transition from conveyor to retort is a significant consideration from the point of view of coal distribution. The number, shape and distribution of tuyeres play an important part in the structure and consistency of the fuel bed. Each of these factors is essential, but it is only within limits that one of them can be varied to make up for deficiencies in another.

In order to maintain the uniformity and stability characteristic of a properly operating anthracite stoker fire, it is necessary that coal be distributed at an equal rate to all parts of the retort circumference. As shown in Fig. 1 the coal must be diverted from its horizontal travel through the conveyor to a vertical flow into the retort. Since this 90 deg turn must be made against the weight of a column of coal already in the retort (often over a foot in height) it is highly important that everything be done to minimize compression. It is at this point that 50 to 75 per cent or more of the degradation takes place. For this reason adaptor castings between the coal worm and the bottom of the retort are so designed as to gradually increase 100 to 200 per cent in cross-sectional area. These adaptors are usually referred to as the *gooseneck* or *throat* of the retort and should be so designed as to eliminate projections, large or small, which might interfere with the flow of coal.

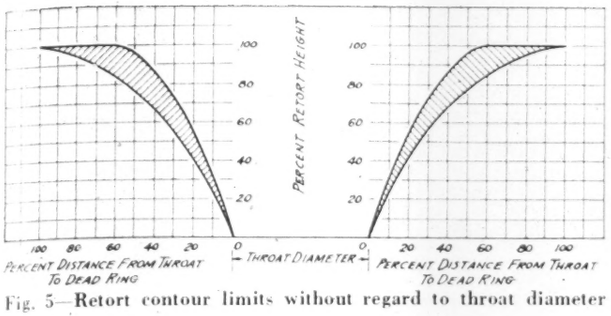

Fig. 5—**Retort contour limits without regard to throat diameter**

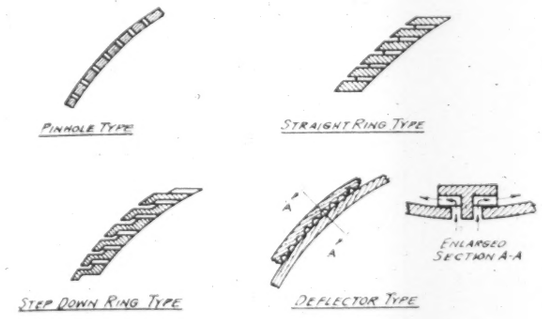

Fig. 6—**Types of tuyeres used in anthracite retorts**

In addition to the proper design of adaptor castings, the point at which the conveyor screw ends has a marked effect upon the distribution of coal in the retort. Unfortunately, although quite critical on most stokers, no generalization can be made.

In the combustion of anthracite, ignition takes place without preliminary coking. The small amount of volatile matter present is probably not released in appreciable quantities until burning actually starts. For this reason retorts of a decidedly shallow nature have usually been found to give best results. In order to bring about combustion in the retort at the rapid rate required, sufficient air for ignition is brought in contact with the fuel as soon as possible. In like manner ash must be eliminated as soon after it is burned out as is consistent with the maintenance of a satisfactory air seal around the upper edge of the retort.

For reasons already enumerated, one of the outstanding features of anthracite retort design is the ratio between diameter and depth. Thirty-two different models of anthracite stoker retorts included in a recent survey had an average ratio of 3.67 to 1. The depth in this case is taken as the distance between the top of the retort and the top of the throat casting. The ratio in the majority of cases was between 2.7 and 5.2 to 1, indicating the latitude possible. An idea of the shape of typical anthracite retorts is given in Figs. 4 and 5. Fig. 4 shows the actual vertical cross-sectional contour lines for different anthracite stokers varying from 13 in. to 23 in. in diameter. Fig. 5 shows the limits within which these various contours occur when they are corrected for variations in throat diameter. The shaded area is that within which the retorts of Fig. 4 fall.

The combustion performance of anthracite retorts is measured in terms of the number of pounds of coal efficiently burned per hour per square foot of horizontal projected grate area, the latter being arbitrarily considered as that falling in a plane bounded by the circumference of the retort. The actual *active* area is somewhat smaller and is ordinarily determined by the diameter of the circle formed by the outer tuyere or tuyeres. For the majority of retorts the active area falls between 35 and 50 per cent of the grate area and averages approximately 42 per cent. Thus, 58 per cent of the average (projected) retort area is devoted to the dead plate. This inactive ring over which the nearly consumed fuel passes serves a double purpose. Primarily, it keeps the remaining combustible in contact with the air stream in order to maintain combustion until the rate of heat loss lowers the temperature below the ignition point. This is necessary since, unlike bituminous coal, anthracite will not continue to burn after it is removed from the air stream. The second function of the inactive ring is to maintain a seal of ashes around the fire to prevent the escape of excess air.

The air ports or tuyeres in an anthracite retort should be so located as to permit a finely divided and low velocity air stream to penetrate the fuel bed as thoroughly as possible. The passage of pieces of coal through alternate zones of air blasts and no air causes the rapid formation of clinker. Likewise anything which tends to cause *channeling* of the air either through the fuel bed or along the edges of the retort will result in the same difficulty. For this reason it is important that the windbox be so constructed as to deliver air at an equal pressure to all points at the same horizontal level in the retort. The velocity and amount of air as it enters the fuel bed on the other hand may decrease proportionately as the fuel bed becomes thinner. Fig. 6 shows cross-sections of various types of tuyeres used in anthracite retorts. These tuyeres may be divided into two general classifications: (*a*) the plate pinhole type which consists of relatively thin castings through which tuyere holes are drilled or cored; this classification includes both the segmental design in which a number of identical castings (usually 6 or 8) are arranged together to form the retort surface, and the type in which the entire active retort surface is in one piece; and (*b*) the ring type in which rings of increasing diameter are placed one above the other so as to form the grate surface with annular tuyeres between each ring. Another tuyere used by one manufacturer is designated in Fig. 6 as the deflector type. Here air passes between a series of blank segmental plates and impinges upon deflector castings which spread it parallel to the plates. Sufficient turbulence is thus caused to make the air diffuse evenly into the fuel bed.

Tuyeres may also be classified in accordance with whether or not they permit the passage of fines into the windbox. For example, the pinhole type tuyere usually permits a certain amount of fine coal to drop through in spite of the opposing air pressure. On the other hand, the step type ring tuyere is effective in preventing this occurrence. Whether or not fines drop into the windbox is relatively unimportant since in the first place the more fines removed the less fly ash there will be, and secondly it is usually fairly simple to devise a suitable automatic or manual fines release.

A study of 12 approved anthracite stokers shows that the actual tuyere openings average very close to 0.5 sq in. per pound of coal at rated capacity. It is improbable, however, that this should be considered a basic design

principle, since better performance is nearly always possible at lower combustion rates. It represents an average lower limit for good performance. The use of a greater tuyere area, if practical means could be devised to do so, would probably improve combustion conditions, particularly if it were accomplished by increasing the number of air ports.

Recent Developments in Anthracite Stokers

A number of very interesting developments relating to stokers have been recently worked out by Anthracite Industries Laboratory and carried to various points beyond the experimental stage. Four of these are particularly outstanding, and as they are indicative of what may be expected in the near future, it will probably be of interest to describe them briefly.

The automatic ignition of anthracite fires has for many years been considered impractical. Nevertheless, it has recently been put upon a commercial basis as a result of cooperation between the laboratory, a large manufacturer of electrical equipment, and a control manufacturer. Stoker manufacturers may now purchase a complete resistance unit for insertion in place of the lower part of the inside retort surface. This resistance unit carries the manufacturer's standard production guarantee. When used in conjunction with the proper control it permits the lighting of an anthracite burning stoker by means of a push button located at any convenient place in the house. Obviously, it may also be wired to an automatic control which causes the fire to relight whenever required. The current consumption is about ½ kwhr per operation.

It will be noted that as contrasted with bituminous stokers, the small anthracite burners referred to in this paper are equipped with circular retorts. The problem of coal distribution has been the main stumbling block which has stood in the way of progress upon anthracite retorts of other shapes. After an intensive study of the coal distribution problem, a rectangular retort was developed which spilled ashes off its four edges. It was found, however, that it is possible to impart sufficient sideward thrust in a narrow, rectangular retort to enable the construction of a side feed burner having a length at least double its width. This has opened up a completely new field to domestic anthracite stokers, for as long as retorts are limited to a circular shape, it is impossible in many cases to provide sufficient input in long, narrow boilers. An additional advantage of the new rectangular retort is the fact that it may be made of cast-iron laminations in such a manner that it may be varied in length at the time of installation in accordance with field conditions encountered. Unfortunately, at the time of writing this paper it is not possible to disclose construction details. However, it is hoped to make them available to all stoker manufacturers in the near future.

The development of a practical and successful vertical ash conveyor has opened new possibilities for the solution of the ash removal problem. This conveyor is applicable to existing stoker ash removal systems. It carries the ashes vertically to whatever height necessary, while an overhead horizontal conveyor removes the material to any desired point. This enables removal of ashes from the cellar or to ash containers, pits, or bins located in the cellar or outdoors.

A new development of considerable interest and now on the market is a small stoker designed for the combustion of barley size anthracite. This stoker has a retort 7 in. in diameter and is extremely simple and inexpensive in construction. It has a combustion rate which may be varied from about ¼ lb per hour to nearly 3 lb per hour. It is used principally for automatic domestic water heating, but is being adapted for use in kitchen ranges, space heaters, and other applications. Combustion rates up to 5 and 7 lb per hour are obtainable by the use of slightly larger retorts. It is quite probable that the same design principles used in this stoker will be applied to larger sized units for house heating. When the potential market for stokers is realized, it does not take very much imagination to foresee the tremendous possibilities of a low priced unit such as this made largely of stampings and die castings.

Conclusion

The domestic anthracite stoker industry has completely emerged from an early period of trial and error engineering, during which time many important lessons have been learned. It is with the hope of diffusing some of the knowledge gained by various experimenters that those design features of particular importance in conventional anthracite burners of small size have been discussed at some length. That the future holds much promise for this industry from the angle of consumption is shown by the steadily increasing demand in spite of strong competition and other adverse circumstances.

That much may be expected along lines of technological advance is confirmed by the many new devices and inventions already waiting to be applied by aggressive manufacturers.

Acknowledgment

Much information used in this paper was supplied by the following individuals to whom the author wishes to express his sincere appreciation: G. Crocker, C. Crowley, C. H. Hall, G. M. Peltz, A. Rogers, and M. A. Young.

[Part 2 to be published in June]

Pittsburgh Chapter Meeting

March 13, 1939. The meeting of Pittsburgh Chapter was called to order in the private dining room of Stouffer's Restaurant by F. C. McIntosh, who presided, and 70 members and guests were present.

Acting Secretary C. M. Humphreys read the minutes of the February meeting, which were approved as read.

L. S. Maehling, treasurer, gave his report and Chairman G. G. Waters of the Program Committee announced that the April meeting had been reserved for the report of the *National Board of Fire Underwriters* Code Committee.

Mr. Waters introduced F. J. Kurth, of New York, who discussed Theory and Practice of Air Distribution in Air Conditioning.

The meeting adjourned at 9:45 p. m., according to the report of Secy. T. F. Rockwell.

Application of Summer Weather Data in Design

By John Everetts, Jr.* (*MEMBER*), New York, N. Y.

THE method of determining weather design data for the four summer months to be used in air conditioning and other heat exchange problems where the variations of atmospheric conditions are important has been covered in a paper Analysis of Summer Weather Data in the United States by J. C. Albright. It is the purpose of this paper to demonstrate the practical application of these data in air conditioning.

An analysis will first be made to segregate the various components of the load on an air conditioning system and to identify the various portions of the data given in the paper referred to with the corresponding sections of the design. To demonstrate the actual use of the data in design, a typical air conditioning problem will be assumed covering four representative cities and the calculated loads resulting from the use of the weather design data will be analyzed and compared.

The only function of an air conditioning system is to maintain a specified atmospheric condition within an enclosure irrespective of the existing conditions outside the enclosure. Aside from the fixed loads of people, lights and motors, the design of an air conditioning system and equipment is dependent entirely on the variations and intensities of the dry-bulb, wet-bulb and dew-point temperatures, solar radiation, and wind effect, and it is therefore necessary that these weather factors be properly chosen so that the system and equipment as designed will do its specified duty and still be within the limits of economic consideration. Heretofore, the choice of design conditions has been made through long years of experience, rough perusal of Weather Bureau reports where these reports were available, and trial and error methods. These methods led to a considerable variation in specified design conditions and when used in the calculation of a system, rendered that system either inadequate to meet the demands which existed or made it so large as to be economically unsound for the particular duty. For example; in New York conditions have been specified ranging from 90 to 98 F for dry-bulb and from 72 to 80 F wet-bulb, with no consideration for the dew-point. The design temperatures for New York as shown in the paper previously cited are 90.7 F dry-bulb, 75.0 F wet-bulb, and 72.4 dew point; each temperature having been chosen by combining the analysis of Weather Bureau data and the practical requirements of an air conditioning system.

The treatment of atmospheric air is made complex by the fact that it is a mechanical mixture of dry air and water vapor involving sensible heat, latent heat and total heat, each of which is a function of either dry-bulb, wet-bulb, dew-point, or various combinations of these temperatures.

These interrelated functions are further complicated by the fact that while the increase in sensible heat is proportional to the increase in dry-bulb temperature, the increments of latent heat are non-uniform for equal temperature ranges in different parts of the wet-bulb scale.

Load Determinations

It has been shown that the dry-bulb, wet-bulb, dew-point, sunshine, and wind movement vary considerably over the country and vary independently of each other, with no co-incidental relationship. These weather factors affect an air conditioning system in two ways, (1) total load, and (2) apparatus design. To analyze the total load, it must be divided into its component parts and each part separately considered with the weather factor by which it is affected. The component parts of the total load for the purposes of such analysis are (1) transmission, (2) ventilation, (3) solar radiation, and (4) internal load.

Transmission Load

The transmission load of an air conditioning system is purely a sensible heat load and is dependent upon variations in dry-bulb temperature and wind movement. The wind movement is only a minor consideration in this connection inasmuch as it has been taken into account in the preparation of the tables showing heat transfer factors for the particular walls and glass enclosing the conditioned space. The maximum daily wind velocity occurs at the time of maximum dry-bulb temperature but very seldom exceeds the 15 mph upon which the heat transfer factors are based in the tables and, therefore, may be neglected in the transmission load but must be considered in the ventilation load as infiltration.

The only other variable is the dry-bulb temperature, but, as small changes in this factor have a major effect on the total transmission load, it is necessary that the

Table 1—Temperature Data[a]

City		New York	Pittsburgh	Kansas City	New Orleans
Design Temperature	D.B.	90 7	91 2	101 5	92 3
	W.B.	75 0	72 6	75 5	80 1
	D.P.	72 4	69 7	71 5	77 9
Noon Avg	D.B.	75 8	77 8	83 7	86 1
	W.B.	65 7	65 3	67 9	74 8
	D.P.	59 6	57 7	59 2	70 1
Normal Max.	D.B.	100 0	98 0	109 0	95 0
	W.B.	81 0	79 0	79 0	83 0
	D.P.	78 0	74 0	76 0	81 0
9 A.M.— 5 P.M. Avg	D.B.	78 8	77 8	84 1	85 5
	W.B.	67 2	64 7	68 4	76 5
	D.P.	61 2	57 3	60 2	73 0

[a] All temperatures are in degrees Fahrenheit and refer to the four summer months.

*Air Conditioning Engineer.

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choice of a proper outside dry-bulb temperature be made with much greater care than needed in the consideration of wind. This selected temperature, hereafter referred to as the *design dry-bulb* is given in Table 1 for the four cities selected for analysis.

With a constant maintained condition in a conditioned space the transmission load will vary directly with the dry-bulb temperature. As the design dry-bulb for Kansas City is higher than that of New York, the transmission load for a given space will be higher for Kansas City than for New York in proportion to the difference between the design dry-bulb and the maintained dry-bulb. While the absolute value of the transmission load in tons is proportional to the dry-bulb differential, the percentage of transmission load to the total calculated load is not proportional to the dry-bulb differential because the total load is affected by the other fixed and variable components of the total loads.

The transmission load based on maximum dry-bulb temperatures apparently indicates that in some cases the load will be double or more that calculated on the basis of the design dry-bulb. This is particularly true of cities having a wide range of daily and seasonal temperature, such as New York. These calculated maximum loads are not real demands upon the air conditioning system as these peak temperatures occur so infrequently and are of such short duration that the flywheel effect due to the heat lag in the wall will prevent the extreme temperatures from causing an exorbitant overrun of maintained temperature. Spaces having large window areas will be affected more quickly by extreme conditions since there is practically no heat lag in glass and the effect will vary directly with the glass wall ratio. The total effect of this increased transmission load is also proportional to the ratio of the transmission load to the total load which will reduce the overall effect in proportion to this ratio.

As the outside dry-bulb falls off, the transmission load will be reduced until the outside dry-bulb is equal to or slightly below the maintained dry-bulb. However, it is erroneous to assume any reduction in operating load due to the outside dry-bulb falling below the maintained condition because of the heat lag in the building and the desirability of having a lower inside temperature as the outdoor temperature falls.

Ventilation Load

The ventilation load is the load produced by the outside air brought into the conditioning system to provide ventilation for the occupants and to offset any possible infiltration into the conditioned space. Infiltration is a direct function of the wind velocity and should be calculated in accordance with the GUIDE procedure to determine whether the infiltration or ventilation requirements are the greater. The larger amount should then be used as the quantity of outside air to be conditioned.

As the outside air contains both sensible and latent heat in varying ratios it is necessary to calculate the total heat removal on the basis of wet-bulb temperatures, since the total heat content of the air is constant for a given wet-bulb temperature regardless of the variation of the sensible-latent heat ratio. The total heat increase per degree in wet-bulb temperature is not constant but increases as the wet-bulb temperature increases. This fact is important in those localities where high wet-bulb temperatures are predominant, and in problems where the outside air quantity is appreciable. As variations in design wet-bulb mean greater changes in calculated load than equal changes in design dry-bulb, it is essential that the proper wet-bulb temperature be used in the calculation of the ventilation load. These *design wet-bulbs* as set forth for the four reference cities in Table 1, indicate the wide variations encountered in different parts of the country.

Ventilation loads based on maximum wet-bulbs will have more of an effect on the total load than that of excess transmission. First, the effect of wet-bulbs higher than the design have an immediate effect as there is no lag in the effect of the wet-bulb on the system. Secondly, the ventilation load is a much greater part of the total load than any other individual item with the exception of certain industrial problems, and third, as the wet-bulb increases the total heat per degree increases to give an accumulative effect to the overload condition.

The compensating features which reduce the value of this overload are (1) the infrequency of occurrence of excessive wet-bulb temperatures, (2) the short duration of their existence, (3) the available overload capacity of a system, and (4) the fact that the maximum wet-bulb, does not generally occur at the same time as the maximum dry-bulb, consequently the transmission load is less than the designed value which will offset part of the ventilation overload.

The ventilation load, contrary to the transmission load, can be assumed to reduce the operating load as the wet-bulb temperature falls. If a suitable air washer is used, it is possible and quite practical to do evaporative cooling whenever the outdoor wet-bulb is at or below the required delivered dew-point.

Solar Radiation

The load caused by solar radiation is entirely sensible heat and is considered either as additional heat transmission or as a separate sensible heat load depending upon the estimator's choice of method by which this load may be calculated. Since the data available and the method of calculation of this load are at present of such nebulous nature, discussion of them is omitted. As the solar radiation is a small proportion of the total load in the problem chosen it is considered best to include it as part of the internal load as a constant throughout the comparative calculations.

Internal Load

The internal load consists of both sensible and latent heat produced by people, lights, motors, and other miscellaneous heat producing sources. Since this load is not affected by any of the weather factors it may be considered as a constant in comparing similar problems in different locations.

Apparatus Design

The choice of air conditioning apparatus is definitely influenced by the dry-bulb, wet-bulb and dew-point temperatures, depending upon the type of system selected.

An air washer system is affected only by the wet-bulb temperature and, therefore, need only be designed for a

total heat removal from entering to leaving wet-bulb. As the total heat is constant for a given wet-bulb temperature, the dry-bulb and dew-point are unimportant in the design of this type of system and the wet-bulb differential to be maintained determines the operating characteristics.

A chemical dehumidifying system is affected by both the wet-bulb and the dew-point, the wet-bulb indicating the total heat to be removed from the system and the dew-point indicating the total amount of moisture to be removed. The absorber capacity and regenerator design in a chemical dehumidifying system are fixed by the amount of moisture to be removed, which value is a function of the dew-point temperature.

The dew-point existing at the time of simultaneous occurrence of the design dry-bulb and wet-bulb temperatures would be too low a value, and would result in the installation of inadequate chemical dehumidifying equipment. Instead, the design dew-point temperature should be used and considered to exist simultaneous with design wet-bulb temperatures for purposes of fixing the capacity of such apparatus. Referring to Table 2

Table 2 Coincident Temperatures[a]

City	New York	Pittsburgh	Kansas City	New Orleans
D. B. Coincident for Design W. B. and Design D. P.	81.5	79.0	85.5	86.5
D. P. Coincident for Design D. B. and Design W. B.	68.5	64.0	63.0	75.5

[a] All temperatures are in degrees Fahrenheit and refer to the four summer months.

where these design dew-points are shown for the four cities analyzed, it can be readily calculated that for Kansas City the moisture removal based on 71.5 dew-point would be more than three times that required for a dew-point of 63 F when reducing both to a required dew-point of 58 F. The same calculations for New Orleans show only an increase of 19 per cent, which can readily be understood by comparing the range of the dew-point temperatures of the two cities, as that for New Orleans indicates small daily and seasonal changes, while that for Kansas City shows wide variations in daily and seasonal range.

Cooling coil capacities are affected by dry-bulb, wet-bulb, and dew-point temperatures and consequently, must be designed on the basis of these three temperatures being coincident. The dry-bulb temperature affects the mean effective temperature (M.E.D.) between the air and the coil surface; the total heat removal of the coil reflects the wet-bulb temperature; and the dew-point varies the transfer rate of the coil by changing the sensible-latent heat ratio. The capacity of the coil decreases with a decrease in dry-bulb and increase in dew-point temperature; hence, the design should be predicated upon the relatively low dry-bulb which occurs with design wet-bulb and design dew-point conditions. The dry-bulb temperatures coincident with the wet-bulb and dew-point design conditions are shown in Table 2 for the four cities indicated and may be compared with the design dry-bulbs as indicated in Table 1.

Problem

The example used for comparison is that of a small store for which the maintained conditions in the occupied spaces are 80 F dry-bulb, 67 F wet-bulb, and 60 F dew-point, and the delivered dew-point is 58 F. The load values given in Table 3 are calculated on the basis of the design temperatures in Table 1 and for operating

Table 3—Design Load

City	New York		Pittsburgh		Kansas City		New Orleans	
Load	Tons	Per Cent	Tons	Per Cent	Tons	Per Cent	Tons	Per Cent
Trans.	3.1	13.8	3.3	16.4	6.2	24.1	3.5	12.2
Vent.	8.2	37.0	5.7	28.5	8.5	33.1	14.4	49.8
Int. Load	10.9	49.2	10.9	55.3	10.9	42.8	10.9	38.0
Total	22.2	100.0	19.9	100.0	25.6	100.0	28.80	100.0
Ratio to Pittsburgh.	1.11		1.00		1.29		1.45	

hours from 9 A. M. to 5 P. M. six days per week during June to September inclusive. Pittsburgh has been taken as a base and the other cities have been compared with Pittsburgh to show how the results vary. The four cities chosen cover a considerable range in design, maximum, and average temperatures. It is of interest to note that while some locations have the same average temperature conditions, they do not have the same design values, and that other cities show higher design temperatures against lower noon averages. This is also true for maximum temperature comparisons and definitely indicate that maxima and averages are no criteria upon which to base the design of a system.

Design Load Analysis

The design load as shown in Table 3 is based on the design temperatures given in Table 1 for the four cities indicated, and the maintained conditions given in the problem.

It will be noted that the transmission load for New Orleans is higher than that of either New York or Pittsburgh, yet is the lowest in terms of percentage of total load. This is due entirely to the exceptionally high ventilation load which is the greatest of the four cities in both calculated load and total load. Pittsburgh shows the lowest ventilation load by virtue of its low design wet-bulb and also the lowest total load because of both its low design dry-bulb and wet-bulb.

The most important relationship in the design load analysis is the ratio of total loads to Pittsburgh. With similar jobs in Pittsburgh and New Orleans this analysis shows that the capacity of the system in New Orleans must be 45 per cent greater than that for the same system in Pittsburgh. This relationship is of particular importance to the manufacturers and engineers who recommend and specify a given sized unit for rooms of equal cubage and located in different parts of the country.

Maximum Load Analysis

The calculations of maximum loads given in Table 4 are based upon the normal maximum dry-bulb and wet-bulb temperatures given in Table 1, and calculated in

Table 4—Maximum Load

City	New York		Pittsburgh		Kansas City		New Orleans	
Load	Tons	Per Cent	Tons	Per Cent	Tons	Per Cent	Tons	Per Cent
Trans.	5.6	18.3	5.2	17.3	8.1	26.1	4.2	12.7
Vent.	14.0	46.0	13.9	45.7	13.5	40.8	18.0	54.5
Int. Load	10.9	35.7	10.9	37.0	10.9	33.1	10.9	32.8
Total	30.5	100.0	30.0	100.0	32.5	100.0	33.1	100.0
Ratio to Pittsburgh	1.02		1.00		1.08		1.10	
Max./Des.	1.38		1.51		1.27		1.15	

the same manner as for the design loads. It has been shown in the previously mentioned paper that simultaneous occurrence of maximum dry-bulb and wet-bulb conditions is impossible. However, the effective transmission load equivalent to that of maximum temperature may occur at the same time as maximum wet-bulb temperatures, due to high heat capacity of walls and the building-up of high temperatures in these walls during such times as a week-end shut down period.

Kansas City has the highest transmission load of the four cities, while New York and New Orleans are equal in ventilation load. New York shows a greater total load than New Orleans which is an absurd conclusion as common sense would dictate and is further evidence that maximum temperatures should definitely not be used in the design of a system. The ratio of the total maximum load to that of Pittsburgh shows surprisingly little variation, while the ratio of the maximum load to the design load for each city varies considerably. The close range of the total loads to Pittsburgh is due to the fact that the maximum temperatures are approximately the same for the four cities. The wide variation in the maximum to design ratio is due to (1) the diurnal march of temperatures, (2) the seasonal temperature range, and (3) the relative frequency of occurrence of high temperatures.

The maximum to design ratio also shows that for Pittsburgh a system 50 per cent larger than that based on design conditions would be required to take care of any possible weather condition which might exist. As the design dry-bulb is exceeded only 2½ per cent of the time, and the wet-bulb exceeded only 5 per cent of the time, a 50 per cent increase in investment cost is a large premium to pay to take care of these exceeded conditions and unless the problem is very special, the economics does not warrant the additional expenditure.

Conclusions

1. With the data given in the previously referred to paper and the analyses of design relations as herein given, the design conditions as specified are adequate for practically all problems in air conditioning, since the exceeded time of 2½ per cent for the dry-bulb and 5 per cent for the wet-bulb and dew-point are of no serious consequence in comfort cooling and commercial air conditioning problems.

2. For the design of chemical dehumidification equipment and cooling coils the coincident dry-bulb should be taken from the combination of design wet-bulb and design dew-point.

3. A further study should be made of solar radiation in cooperation with other Society Research Technical Advisory Committees studying this problem before any design conditions can be properly set up.

Minnesota Meeting Features

Round Table Discussion on Insulation

March 13, 1939. A dinner meeting was held at 6:15 p.m. at the Minnesota Union, University of Minnesota, with 28 members and guests of Minnesota Chapter present. Vice-Pres. I. C. Winterer called the meeting to order and the minutes of the previous meeting were read and approved.

N. D. Adams reported on a recent speaking engagement which he filled for the Society's Speakers Bureau at Winnipeg. He told of an enthusiastic meeting with an attendance of 125 members, wives and guests of Manitoba Chapter.

A short discussion was held on the possibility of a joint meeting with the Manitoba Chapter during the visit of J. F. McIntire, president of the ASHVE, and it was proposed that a Committee be appointed to work out ways and means to arrange a meeting at Detroit Lakes on May 13 and 14. Eleven members expressed themselves as being favorable toward attending a joint meeting of this kind.

R. E. Backstrom, chairman of the committee to study the proposed ordinance submitted to the Chapter relative to regulation of ventilating ducts by the Society, stated that the committee had not had sufficient time to study the proposed ordinance and arrive at an efficient conclusion. He suggested that more time be given them and that it might be well to call a special meeting for interested persons or to discuss this matter at the April meeting. Secy. M. H. Bjerken was instructed to write Headquarters office to determine how much time was available before submitting the Chapter's report.

Secretary Bjerken and Mr. Adams made an announcement relative to the Society's Semi-Annual Meeting to be held at Mackinac Island.

Vice-President Winterer asked the Nominating Committee for a report at the next meeting.

The program was then turned over to Mr. Backstrom, who served as chairman for the remainder of the evening. A Round Table Discussion on Insulation was led by Mr. Backstrom, who gave a brief resumé on Insulation and a short history of the industry, particularly in the Northwest.

Prof. F. B. Rowley brought up the matter of the Continuation Study to be held at the University of Minnesota next year and informed those present that it would be necessary to make reservations six months in advance. Professor Rowley suggested that a committee be appointed in the near future to arrange for plans for another seminar to be held, possibly in December, 1939.

Mr. Backstrom called upon Professor Rowley with reference to findings at the Experiment Station on installation and application of insulation, particularly pertaining to vapor pressures and water vapor. Professor Rowley presented a number of slides and charts covering the subject, which showed how tests were run during the investigation on the study of vapor barriers; also the effect of attic ventilation on the accumulation of moisture within the attic and upon attic temperatures; and the effect of vapor pressures on the rate of vapor travel through materials.

C. E. Lund, University of Minnesota, and D. B. Anderson, Wood Conversion Co., followed Professor Rowley with a talk and showed slides and charts of accumulated data, covering views of apparatus used in making tests on vapor barriers and details of construction for special vapor barrier test apparatus, as well as construction details for attic ventilation. They also showed the test set-up for unventilated and mechanically ventilated attics. A great deal of this information was received in the past year through a cooperative research program to determine the cause of condensation within buildings, its probable extent under various conditions, and the best method of prevention and correction. Pictures and slides of test data compiled for actual tests in a residence proved of special interest.

Before adjournment, a vote of thanks was given to Chairman Backstrom for the complete and interesting manner in which he had arranged for presenting the topic of discussion.

Reactions of Office Workers to Air Conditioning in South Texas

By A. J. Rummel,* San Antonio, Tex., F. E. Giesecke,** W. H. Badgett,*** College Station, Tex., (*MEMBERS*) and A. T. Moses,† San Antonio, Tex.

This paper is the result of research sponsored by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS in cooperation with the Texas Engineering Experiment Station of the Agricultural and Mechanical College of Texas and the San Antonio Public Service Co., conducted under the supervision of the Research Technical Advisory Committee on Sensations of Comfort.

IN THE past there has been some disagreement among air-conditioning engineers as to the most desirable temperature and humidity conditions to be maintained indoors in relation to various outdoor conditions. As a result of the research work done by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS at its Research Laboratory in Pittsburgh and in cooperation with the Ontario Research Foundation of Toronto and the Texas Engineering Experiment Station at College Station,[1, 2, 3, 4, 5, 6, 7] these differences of opinion have been practically eliminated for most localities. However, the optimum indoor conditions for warm climates where the average yearly temperature is fairly high have remained more or less a matter of conjecture and have been the subject of considerable discussion and even lawsuits. In order that this element of doubt might be removed, San Antonio, Texas, situated in one of the warmer regions of the country and with an average yearly temperature of 69.7 F, was chosen by the Technical Advisory Committee on Sensations of Comfort as a desirable location for a study of comfort conditions for office workers during the summer of 1938.

Outdoor temperatures in San Antonio as recorded by the United States Weather Bureau during July and August, 1938, the period in which this study was made, are given in Table 1.

The normal average 24-hour mean dry-bulb temperature from April 1 to October 1 is 78.8 F; from October 1 to April 1, it is 60.6 F, with a year around average of 69.7 F.

During the period of this study, the minimum dry-bulb temperature recorded between 8:00 A. M. and 5:00 P. M. was 74 F and the maximum was 100 F. During those hours, the dry-bulb temperature was 90 F or above approximately 48 per cent of the time and 95 F or above approximately 18 per cent of the time.

The highest dry-bulb temperature on record for the month of July in any year since 1885 is 106 F, and for the month of August it is 107 F.

The average daily percentage of possible sunshine during July and August, 1938, was 85 per cent.

Between the hours of 8:00 A. M. and 5:00 P. M. the minimum wet-bulb temperature recorded was 70 F, the maximum was 77 F, and the average was 74.5 F. During these hours the wet-bulb temperature was 75 F or above approximately 38 per cent of the time.

The building selected for this study was the air conditioned offices of the San Antonio Public Service Co. shown in Fig. 1. It was chosen because of the large number of office workers employed under one management in an air conditioned space; because these employees provided a typical cross-section of office workers in this locality; because of the possibility of accurate control of temperature and humidity conditions in the building; and because of the willingness of the company to cooperate in the work.

Table 1—Weather Bureau Data, San Antonio, Texas

Time of Day		Temperatures, Degrees Fahrenheit					
		July		August		Avg for July and August	
		D.B.	W.B.	D.B.	W.B.	D.B.	W.B.
8:00 A.M.	Min.	74.0	73.0	74.0	70.0		
	Max.	81.0	75.0	82.0	75.5		
	Avg	78.0	74.5	78.3	74.0	78.2	74.2
12:00 Noon	Min.	86.0	72.0	77.0	72.5		
	Max.	93.0	77.0	93.0	76.0		
	Avg	88.8	74.5	89.1	74.0	88.9	74.3
5:00 P.M.	Min.	81.0	74.0	75.0	72.5		
	Max.	98.0	77.0	97.0	76.5		
	Avg	93.2	75.0	91.9	74.5	92.6	74.7
Avg 24 Hours	Mean	85.0	73.2	84.6	73.8	84.8	73.5

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***Research Assistant, Texas Engineering Experiment Station, College Station, Tex.
†Technical Assistant, Texas Engineering Experiment Station, San Antonio, Tex.

[1]Comfort Standards for Summer Air Conditioning, by F. C. Houghten and Carl Gutberlet. (ASHVE TRANSACTIONS, Vol. 42, 1936, p. 215.)

[2]Cooling Requirements for Summer Comfort Air Conditioning, by F. C. Houghten, F. E. Giesecke, C. Tasker, and Carl Gutberlet. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, December, 1936, p. 681.)

[3]Summer Cooling Requirements of 275 Workers in an Air Conditioned Office, by A. B. Newton, F. C. Houghten, Carl Gutberlet, and R. W. Qualley. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, December, 1937, p. 758.)

[4]Cooling Requirements for Summer Comfort Air Conditioning in Toronto, by C. Tasker. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, June, 1938, p. 405.)

[5]Shock Experiences of 275 Workers After Entering and Leaving Cooled and Air Conditioned Offices, by A. B. Newton, F. C. Houghten, Carl Gutberlet, R. W. Qualley, and M. C. W. Tomlinson. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, July, 1938, p. 481.)

[6]General Reactions of 274 Office Workers to Summer Cooling and Air Conditioning, by F. C. Houghten, A. B. Newton, R. W. Qualley, and Edward Witkowski. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning, August* 1938, p. 552.)

[7]Seasonal Variations in Effective Temperature Requirements, by F. E. Giesecke and W. H. Badgett. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, October, 1938, p. 677.)

Presented at the 45th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1939.

Fig. 1—Air conditioned office building of the San Antonio Public Service Co. in which the study was made

The personnel of the offices in which the study was made was limited to that on the second and third floors, shown diagrammatically in Fig. 2, and consisted of 94 persons, of whom 72 (77 per cent) were men and 22 (23 per cent) were women. The group varied in age from under 20 years to past 60 years.

During the summer the men did not wear their coats while in the office, and the women wore light summer dresses. Working hours were from 8:00 A. M. to 5:30 P. M., with a lunch period of an hour and a half.

In the preliminary observations of dry- and wet-bulb temperatures which were made with an electric indicating psychrometer at each of the 94 desks occupied by the subjects used in the study, it was found possible to divide the entire space on the second and third floors of the building into 25 zones in each of which the effective temperature was very uniform.

During the first week of the study, temperature observations were made twice each day in each of the 25 zones. By the end of the week it became evident that the space could be divided into 7 zones as indicated in Fig. 2, in each of which there was practically no variation in effective temperature.

In the large offices, particularly along the south side of the building, it was expected that on the desks near the outside wall the effective temperature would be a little higher than on the desks nearer the center of the building, due to radiation from the sun and to absorption of radiant heat by the wall itself. However, no significant difference in effective temperature was noted after a large number of observations. This unexpected uniformity of temperature distribution can be attributed, no doubt, to the fact that the air supply grilles are located quite high and the air is discharged toward the outside wall, striking the wall and dropping before reaching the breathing line in any part of the office. Venetian blinds are installed on all windows and their full length is used at all times. All illumination is supplied from indirect sources. The reactions of persons near the windows and walls exposed to the afternoon sun were compared with those in the center of the building and those on the shaded side of the building, and for the same effective temperature there seems to be very little difference, if any, in their sensations of warmth.

The actual collection of data for use in the study was begun on Monday, July 11, and was continued for 7 weeks, observations being made on 5 days each week. Each morning a questionnaire, as shown in Fig. 3, was given to each employee and at the same time the questionnaires for the preceding day were collected. In order that each individual might fully understand the purpose of this study, and in order that all interpretations of reactions might be as nearly uniform as possible, a certain amount of *coaching* was given each person during the first week. On the questionnaire each employee recorded his feeling of warmth at 8 different times during the day—immediately before and immediately after the morning and noon entrances into the building, and immediately before and after the noon and evening exits from the building. He also recorded his feeling of warmth during the preceding night. The information obtained from the questionnaires was used in studying the feeling of shock on entering or leaving an air conditioned building under various conditions.

Twice each day the dry-bulb and wet-bulb temperatures were observed in each zone and each occupant was asked to state his feeling of warmth at that moment, which was recorded on the data sheet shown in Fig. 4. This information was used in the study of comfort conditions for office workers in an air conditioned building.

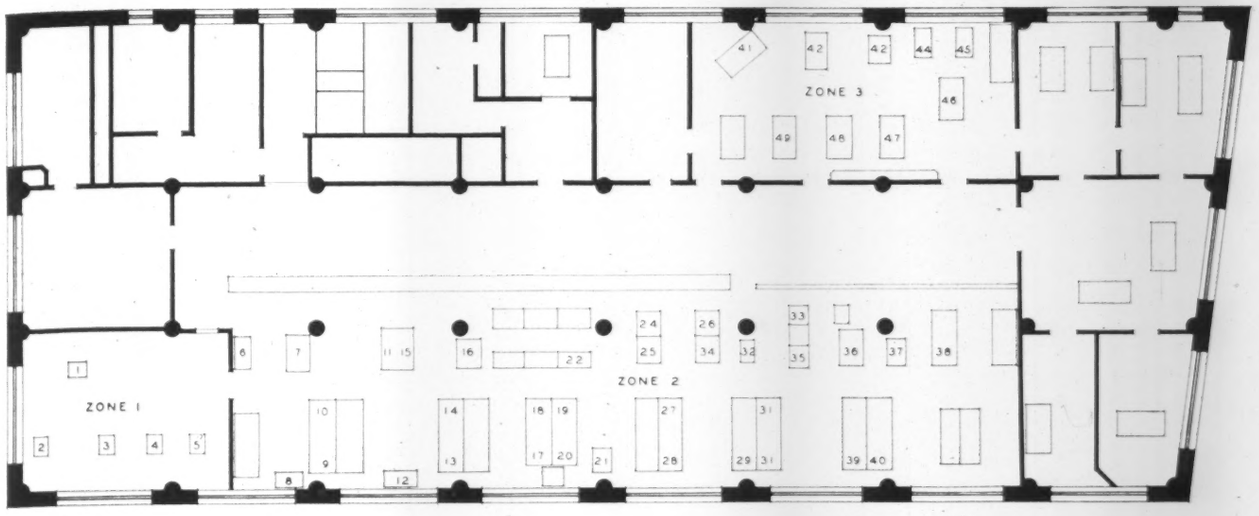
These data indicate rather definitely that, in spite of the mild winters and the intensity and duration of the summer heat in San Antonio, there is very little difference in the optimum effective temperature for indoor comfort in this locality as compared to other localities where similar investigations have been made. Because of the fact that the average outdoor temperature is much higher in the southern part of Texas than in the northern states, it has been commonly believed that indoor conditions somewhat warmer than the optimum for those localities would be entirely satisfactory. A previous study conducted at the Agricultural and Mechanical College of Texas at College Station, Texas[8] had indicated that such a belief was erroneous, but, because of the small number of subjects used in that study, and because of the fact that they were all young men and in good health, the results were not conclusive. The study just completed, however, has substantiated the results indicated by the Agricultural and Mechanical College of Texas study, and, for the sake of comparison, the San Antonio results have been plotted on a curve from the College Station study, as shown in Fig. 5.

There is no doubt that people who live in warm climates become acclimated, but the extent of that acclimatization is evidently not so great as it was formerly believed, and, even though inhabitants of warm climates can apparently withstand somewhat higher temperatures without suffering ill effects, they are not necessarily comfortable while doing so.

The study of the daily reactions of all employees indicates that optimum indoor conditions are not appreciably affected by short-period fluctuations in the outdoor temperature.

The results of the study of comfort conditions are

[8]Loc. Cit. See Note 7.



SECOND FLOOR

NOTE NUMBERS IN RECTANGLES INDICATE LOCATION OF SUBJECTS

THIRD FLOOR

Fig. 2—Air conditioned office space in which the study was made

No. 18 Study of Comfort Conditions in San Antonio, Texas, during the Summer of 1938, by the San Antonio Public Service Company, the Texas Engineering Experiment Station at the A. & M. College, and the American Society of Heating and Ventilating Engineers.

NAME C Jones DATE 7-26-38

	SENSATION OF WARMTH C	MC	I	MW	W	DEGREE OF PERSPIRATION 0	1	2	3	4
1 Morning reaction to outdoors			✓			✓				
2 Reaction upon entering office in morning			✓			✓				
Duration of reaction			30 min.							
3 Reaction before leaving office at noon			✓			✓				
4 Reaction to outdoors immediately after leaving office at noon				✓			✓			
Duration			1 hour							
5 Reaction to outdoors immediately before entering office after noon			✓				✓			
6 Reaction immediately after entering office after noon			✓			✓				
Duration			10 min.							
7 Reaction before leaving at night			✓			✓				
8 Reaction to outdoors immediately after leaving office at night				✓				✓		
Duration			3 hours							
9 Reaction last night as compared with some individual who did not spend the day in a conditioned space	[ ] Considerably more comfortable [ ] Slightly more comfortable					[ ] Same degree of comfort [ ] Slightly less comfortable [ ] Considerably less comfortable				

10 REMARKS -

KEY TO SYMBOLS

SENSATIONS OF WARMTH

(C) Cool or cold, very uncomfortable

(MC) Mildly cool, slightly too cool for comfort

(I) Ideal or as far as temperature is concerned, no change desired

(MW) Mildly warm, slightly too warm for comfort

(W) Warm or hot, very uncomfortable warm

DEGREE OF PERSPIRATION

(0) Forehead or body dry

(1) Forehead or body clammy

(2) Forehead or body damp (perspiration just visible)

(3) Forehead or body wet (sweat rolling off the surface, frequently to drops)

(4) Perspiration on the head runs down or perspiration on the body runs down or wets the body

Answer questions with check marks.

Give durations of sensations in minutes or in hours and minutes.

Fig. 3—Daily questionnaire to office personnel

LOCATION 16

Study of Comfort Conditions in San Antonio, Texas, during the Summer of 1938, by the San Antonio Public Service Company, the Texas Engineering Experiment Station at the A. & M. College, and the American Society of Heating and Ventilating Engineers.

NAME Miss Selma Eber PERIOD JUL 12 JUL 16

DATE	TIME	ROOM CONDITIONS DB	WB	ET	RH	SENSATIONS OF WARMTH C	MC	I	MW	W	DEGREE OF PERSPIRATION 0	1	2	3	4
	10 00	82	69	76.0	52 %					✓		✓			
12	3 18	82	76	89	76.0	50 %			✓			✓			
	9 55	79	3	66	9 74.0	52 %			✓			✓			
13	3 43	80	06	65	74.0	49 %			✓			✓			
	9 56	77	3	65	2 73.0	52 %		✓				✓			
14	3 51	77	6	65	3 73.0	52 %		✓				✓			
	9 50	80	06	80	74.5	53 %			✓				✓		
15	3 54	80	5	67	5 74.5	50 %			✓			✓			
	9 43	82	3	69	8 76.0	58 %				✓			✓		
16	3 45	78	3	66	0 73.0	52 %			✓			✓			

Fig. 4—Data sheet for recording reactions of office personnel to indoor atmospheric conditions

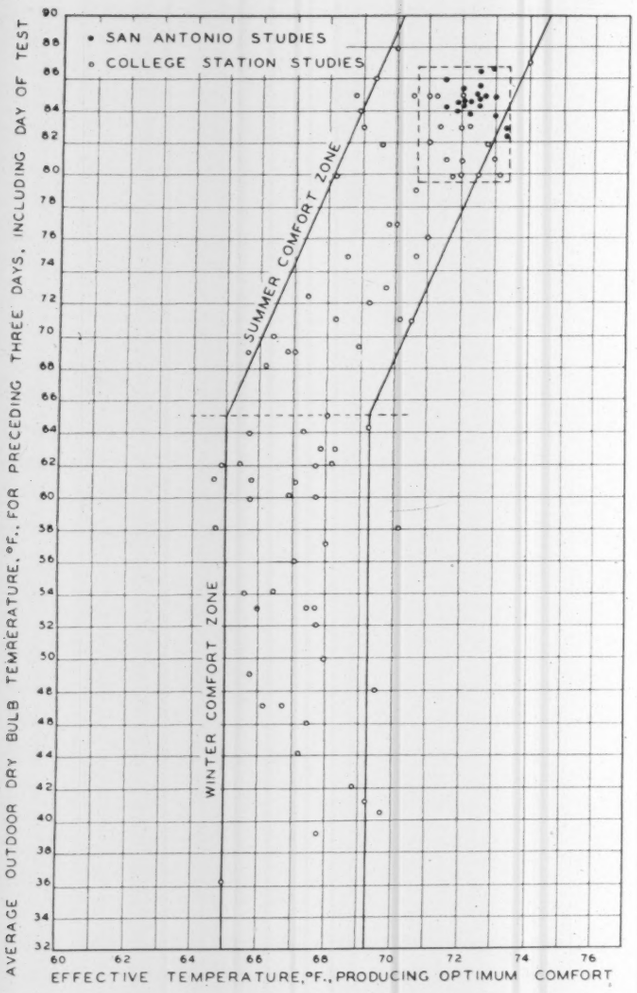


Fig. 5—Comparison of the San Antonio and College Station, Tex., studies. (Each College Station point represents the reaction of 5 subjects and each San Antonio point represents the reaction of 94 subjects)

shown graphically in Fig. 6, in which the percentages of all persons who were comfortable after an hour or more in the air conditioned space are plotted against the effective temperatures at which the observations were made. These effective temperatures are based on air movements in the conditioned space not exceeding 20 fpm.

A superficial examination of the curve would indicate that an effective temperature of 71.5 deg would be ideal insofar as comfort is concerned. However, a more careful analysis of the results shows that at 71.5 deg ET, even though approximately 92 per cent of the subjects were comfortable, the majority of those not expressing a feeling of comfort were mildly cool, which is not desirable. At 72 deg ET approximately 90 per cent were found to be comfortable, 5 per cent mildly cool, and 5 per cent mildly warm. For this condition the relative humidity varied from a minimum of 44 per cent to a maximum of 59 per cent, remaining the greater part of the time between 48 and 53 per cent, with an average of 51 per cent.

A study of the reactions of all the women as compared to the reactions of all the men indicated that the optimum effective temperature for women is about 2 deg higher than the optimum for the men (Figs. 7, 8 and 9). This seems to apply equally to all age groups. The difference in summer comfort requirements for men and for women may be due partly to the difference in the amount of clothing worn.

In any application of air conditioning for human comfort its effect on health must be considered, and the fact cannot be denied that if a person is afflicted with any slight respiratory ailment the condition is aggravated by a feeling of chilliness. Therefore, for any large group of persons of both sexes an optimum effective temperature of about 73 deg is indicated. At 73 deg ET approximately 85 per cent of all persons were comfortable after having been in the building for one hour or more, and of those who were not comfortable only a small percentage was slightly too cool.

In the studies which were made at the Agricultural and Mechanical College of Texas[9] continuously over a period of a year, it was found, as shown in Fig. 5, that the optimum condition of maximum comfort for outdoor temperatures averaging over 80 F varied from about 70.5 deg ET to 73 deg ET with a mean of about 71.5 deg ET. In view of the fact that the subjects in the College Station study wore light-weight coats, whereas those in the San Antonio study did not, there is a remarkable agreement between the two studies when it is considered that wearing a coat makes one comfortable at from 1 to 2 deg lower effective temperature.

The reactions of the different age groups indicate that for both men and women past 40 years the optimum effective temperature is about one-half a degree higher than for those under 40 years as indicated in Figs. 10 and 11.

An attempt was made to determine the effect of health and stature on comfort. The data obtained were not adequate for any definite conclusions, but a few facts were indicated. For all persons whose health would not be classed as perfect the optimum effective temperature seems to be about 1 deg higher than for those in perfect health.

There was no apparent difference in the reactions of slender men and stout men, but the comfort of the women was apparently dependent to some extent upon their size. The stout women indicated a desire for an effective temperature of 1 or 2 deg lower than the optimum for slender women.

It is known that the degree of activity of any individual has a definite effect on his comfort, but sufficient data were not obtained in this study to make a quantitative analysis of that effect.

A study of the reactions of all persons upon entering the air conditioned space, shown in Fig. 6, indicates that, regardless of the differential, there was very little shock felt when the inside effective temperature was not less than 71.5 F. With effective temperatures of less than 71.5 deg there was a noticeable shock, and as the effective temperature was lowered the percentage of persons who were too cool immediately after entering the building rose rapidly.

When the effective temperature was as high as 76 deg inside there were still a few persons who felt mildly

[9]Loc. Cit. See Note 7.

cool on entering, and the percentage of mildly cool votes was about the same at 72 deg ET as it was at 76 deg ET; however, it is interesting to note that when the inside effective temperature was 72 deg, the percentage of persons who were not too cool immediately after entering (approximately 90 per cent) was practically the same as the percentage comfortable after an hour or more in the air conditioned space, whereas, when the effective temperature was 76 deg, the percentage of people comfortable after an hour dropped to approximately 25 per cent.

Each person was asked to indicate on his daily questionnaire (Fig. 3) the duration of his reaction immediately after entering and immediately after leaving the building. For the range of indoor effective temperatures observed, the majority indicated that they felt no shock on entering the building and that their feeling of comfort was no different after several hours in the

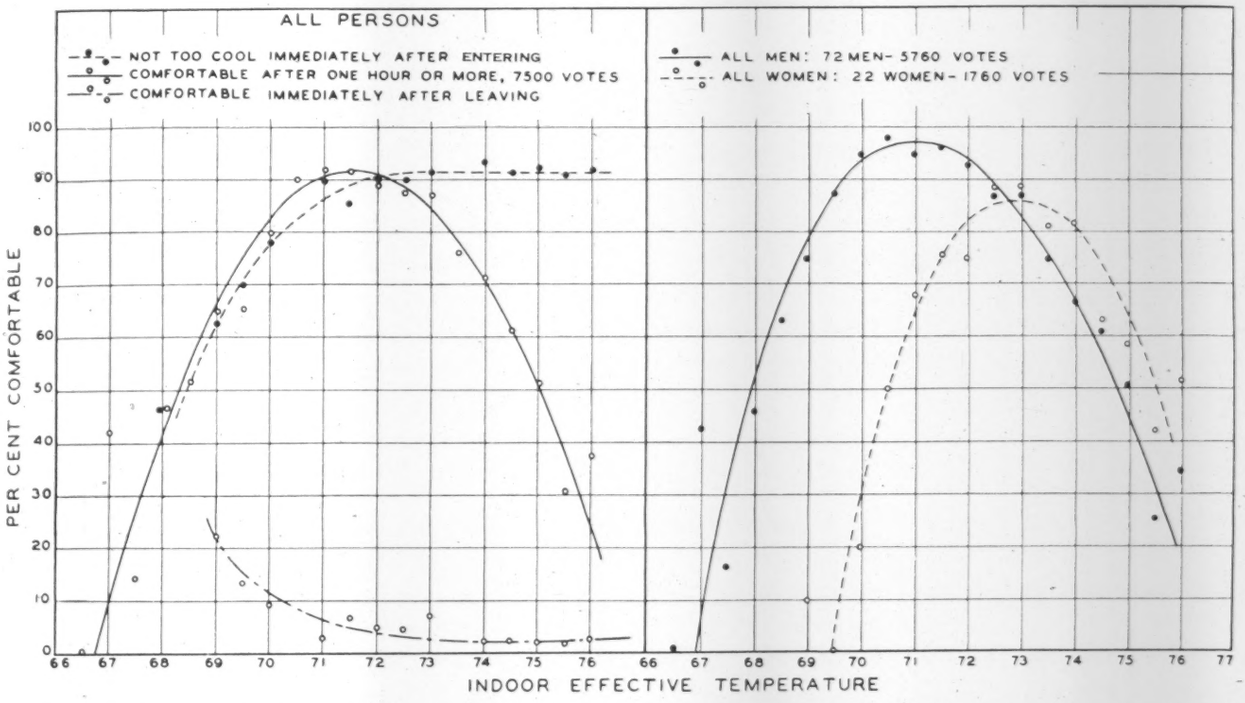

ALL PERSONS
NOT TOO COOL IMMEDIATELY AFTER ENTERING
COMFORTABLE AFTER ONE HOUR OR MORE, 7500 VOTES
COMFORTABLE IMMEDIATELY AFTER LEAVING
ALL MEN: 72 MEN- 5760 VOTES
ALL WOMEN: 22 WOMEN- 1760 VOTES
PER CENT COMFORTABLE
INDOOR EFFECTIVE TEMPERATURE

Fig. 6—Relation between effective temperature maintained in conditioned space and percentage of observations indicating comfort for all persons

Fig. 7—Relation between effective temperature maintained in conditioned space and percentage of all men and of all women indicating comfort

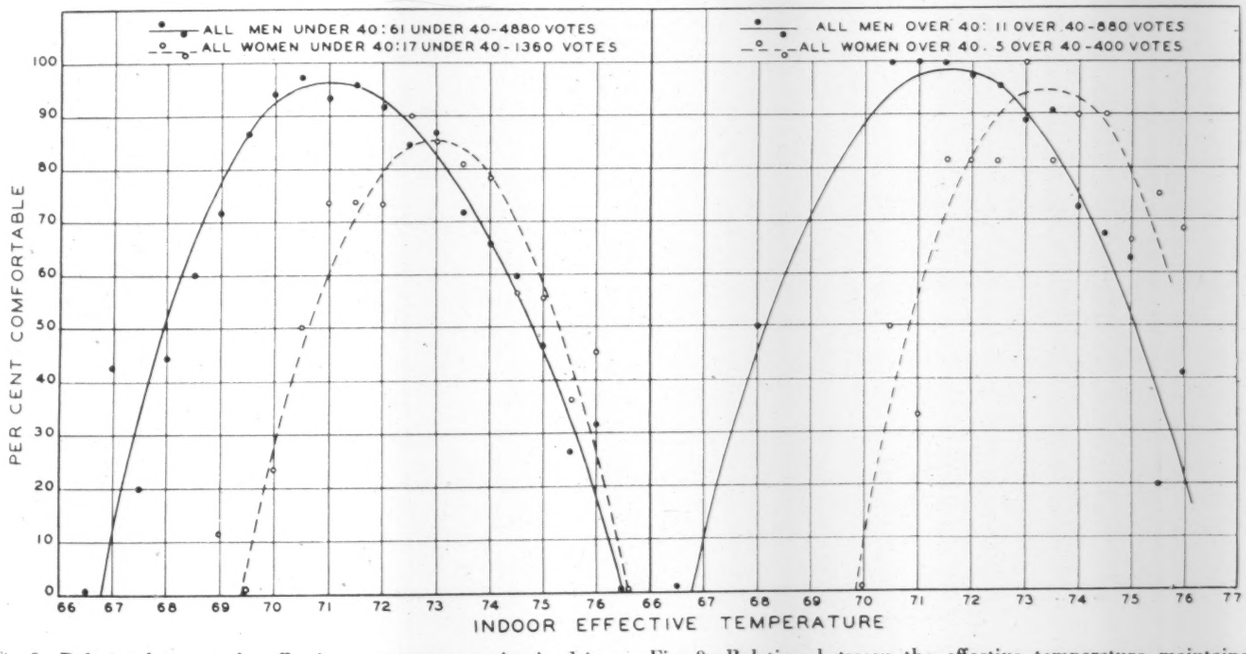

ALL MEN UNDER 40: 61 UNDER 40-4880 VOTES
ALL WOMEN UNDER 40: 17 UNDER 40-1360 VOTES
ALL MEN OVER 40: 11 OVER 40-880 VOTES
ALL WOMEN OVER 40. 5 OVER 40-400 VOTES
PER CENT COMFORTABLE
INDOOR EFFECTIVE TEMPERATURE

Fig. 8—Relation between the effective temperature maintained in conditioned space and the percentage of observations indicating comfort for all men and for all women under forty

Fig. 9—Relation between the effective temperature maintained in conditioned space and the percentage of observations indicating comfort for all men and for all women over forty

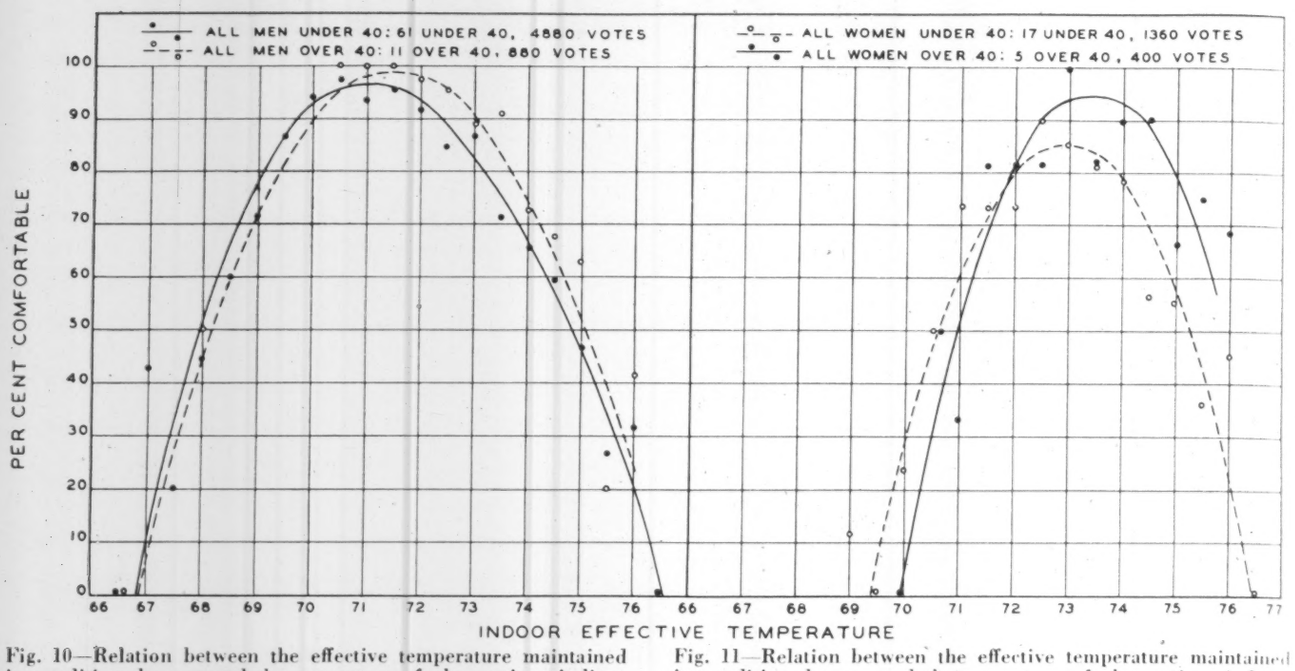

ALL MEN UNDER 40: 61 UNDER 40, 4880 VOTES
ALL MEN OVER 40: 11 OVER 40, 880 VOTES
PER CENT COMFORTABLE
INDOOR EFFECTIVE TEMPERATURE

Fig. 10—Relation between the effective temperature maintained in conditioned space and the percentage of observations indicating comfort for all men under forty and all men over forty

Fig. 11—Relation between the effective temperature maintained in conditioned space and the percentage of observations indicating comfort for all women under forty and all women over forty

conditioned space than immediately after entering. However, for those who did experience a cold shock on entering the building, the durations of the shock were as follows:

Not more than 5 min	29.6 per cent
Between 5 and 10 min	15.9 per cent
Between 10 and 15 min	16.9 per cent
Between 15 and 30 min	22.8 per cent
Between 30 min and 1 hour	9.5 per cent
More than 1 hour	5.3 per cent

When the inside effective temperature was in the vicinity of the lower limit of the comfort zone, there was a noticeable lengthening of the duration of the cold shock on entering the building as shown by the curve in Fig. 12.

The warm shock that is felt by persons leaving an air conditioned building is a sensation that is not easily analyzed. It is needless to say that any condition is emphasized by contrast, but that should not necessarily mean that the condition is harmful because of the contrast. It is not reasonable to expect one to be comfortable in 98 F or 100 F air, even when the contrast between indoors and outdoors is negligible.

In this study an attempt was made to establish the relation between indoors and outdoors, but no definite relation was discernible. The warm shock seems to depend almost entirely on the outdoor temperature. The percentage of persons indicating a shock on leaving was practically the same when the dry-bulb temperature differential was 6 deg as when it was 18 deg.

Practically the entire group expressed a feeling of discomfort immediately after leaving the building. Each individual was asked to indicate the duration of any feeling of discomfort that was experienced on leaving. A number of them stated that they had a feeling of discomfort even after several hours. When a change was felt and the feeling of discomfort disappeared or was lessened, after an hour or more, it was probably due to the fact that the sun had gone down and the outdoor conditions were actually more comfortable. Therefore, in studying the duration of the warm shock, only those individuals were considered who recorded a duration of not more than one hour of discomfort after leaving the building. For that group, which was approximately 35 per cent of all subjects, the durations expressed were as follows:

Not more than 5 min	5.3 per cent
Between 5 and 10 min	5.8 per cent
Between 10 and 15 min	21.9 per cent
Between 15 and 30 min	28.4 per cent
Between 30 min and 1 hour	38.6 per cent

The 65 per cent of the subjects who stated that their feeling of discomfort lasted for more than 1 hour after leaving the conditioned space evidently did not consider their feeling of discomfort as a shock.

The percentage of all persons who were comfortable on leaving the conditioned space was noticeably higher when there were a number who felt mildly cool immediately before leaving as indicated in Fig. 6. In that case the contrast appears to have been pleasing at first rather than oppressive.

Near the end of the study when the employees had become more observant of their feelings of comfort, both in the office and at home, a questionnaire was given to each of them asking for their general reactions to air conditioning and their opinions on its over-all effectiveness. In order that everyone might give sufficient thought to this subject, the questionnaires were not collected until the second day after they had been distributed.

The following 3 questions given were asked in the

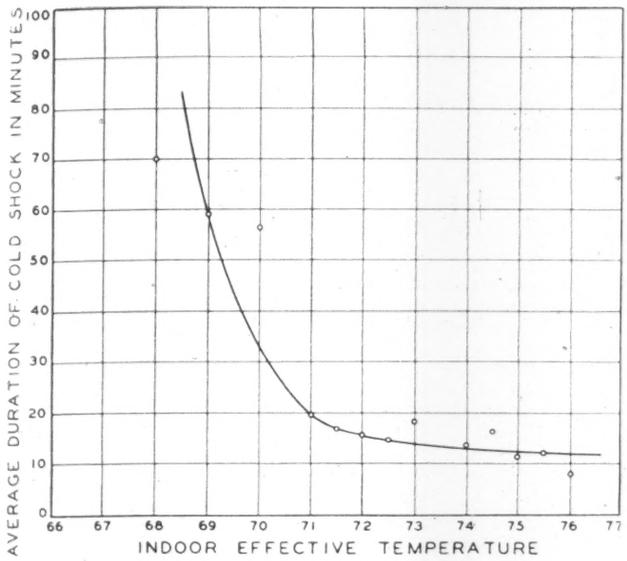


Fig. 12—Relation between the effective temperature maintained in the conditioned space and the duration of cold shock on entering conditioned space

questionnaire that was distributed during the last week of the study:

1. What difference, if any, have you noticed in your reactions this summer after leaving the office on warm days as compared to last summer previous to the installation of air conditioning?

2. Do you think that spending the day in an air conditioned office enables you to withstand the prolonged summer heat better than your friends and associates who are not in air conditioned offices during the day?

3. General remarks on the effectiveness of air conditioning.

Seventy-nine of these questionnaires were filled out and returned. Some of the answers to questions Nos. 1 and 2 were rather lengthy and somewhat vague, but, after each of them had been carefully studied for its exact meaning, and all had been classified, the results were as follows:

In answering question No. 1, the entire group apparently interpreted the phrase *after leaving the office* as meaning *immediately after leaving the office*. Fifty-six per cent stated that they were less comfortable this year than last year immediately after leaving the office; 14 per cent stated that they noticed no difference whatever; and 30 per cent stated that they were more comfortable this year than last year.

Of the answers to question No. 2, 86 per cent were affirmative and 14 per cent were negative.

Some of the answers to question No. 3 were meaningless and a few persons failed to answer it at all; however, most of the answers were very favorable. The percentages were as follows:

Favorable	67 per cent
Meaningless or no answer	23 per cent
Unfavorable	10 per cent

A few typical answers to question No. 3 are given:

I, personally, have developed sinus trouble. Whether it is directly due to air conditioning, I do not know.

I notice especially the quickness with which physical exertion tires and weakens me when I work or play outside in the summer heat.

I do not believe that air conditioning agrees with my health. At different times I have left the building and for 30 min or more have had a chill. At other times I felt very warm.

The temperature seems to be fine, but it is stuffy as if not enough fresh air were getting into the office.

I have not had my usual hay fever this year.

Air conditioning enables one to be comfortable and comfort is life's greatest joy.

It has helped my sinus trouble. It has made summer a pleasant time of the year instead of an ordeal that had to be endured. It has done away with paper weights. It has made it possible for one to maintain a uniform standard of work all the year around.

This is the most pleasant summer I have ever gone through.

A more courteous, cheerful attitude has been noticed in the office since the installation of air conditioning.

I think that the benefits have been very noticeable in myself and my fellow employees in that our energy does not appear to lag in the afternoons during a long, continued hot spell as it did before the installation of air conditioning.

I think that it makes you want to stay at your job in the office where it is cool and comfortable. I am more anxious to come to work since we have air conditioning.

It has been a pleasure to work in our building this summer. One great benefit has been in not having the clothing sticking to the body because of perspiration.

You feel as alive and fresh at the end of the day as you do in the morning.

Great!

The results of this phase of the study have further verified the generally accepted theory that the harmful effects of heat are cumulative, and that prolonged hot weather is not accompanied by the usual *run down* feeling when relief from the heat can be experienced through the hottest part of each day.

Four D's of Air Conditioning Subject of Toronto Address

March 6, 1939. The regular meeting of Ontario Chapter was held in the Royal York Hotel, Toronto, at 6:30 p. m. There was an attendance of 69 members and guests. In the absence of H. R. Roth, M. W. Shears acted as secretary and it was moved and seconded that the minutes be accepted as written.

H. H. Angus, chairman of the Nominating Committee, reported as follows on the action of the Nominating Committee:

For President—H. D. Henion.
For Vice-President—J. W. O'Neill.
For Secretary—H. R. Roth.
For Governors—C. Tasker, F. E. Ellis, J. H. Fox and H. B. Jenney.

President Jenney appointed D. O. Price and W. C. Kelly as auditors.

Mr. Fox introduced the matter of the *Engineering Alumni Association* of the University of Toronto Triennial Award to be given every three years to an outstanding student or to an engineer who has done some outstanding work in a particular branch of his profession. Mr. Fox moved that Messrs. Angus, Tasker and Jenney act as a committee to submit to the *Engineering Alumni Association* the name of an engineer whom they thought worthy of such award.

Mr. Tasker introduced the speaker of the evening, J. H. Van Alsburg Chicago, Ill., who addressed the Chapter on the Four D's of Air Conditioning. At the conclusion of Mr. Van Alsburg's address, J. W. Bishop moved a vote of thanks to the speaker which was heartily concurred in by all those present.

The Rôle of the Extremities in the Dissipation of Heat from the Body in Various Atmospheric and Physiological Conditions

By Charles Sheard, Ph.D.,* Marvin M. D. Williams, Ph.D.,**
Grace M. Roth, Ph.D.,*** and Bayard T. Horton, M. D.,† Rochester, Minn.

THE human body adjusts itself to low environmental temperatures chiefly by constriction of the peripheral blood vessels and to high atmospheric temperatures largely by an increase of sweat subsequent to maximal vasodilatation of the peripheral vascular system. The investigations of Burton,[1] Burton and Bazett,[2] and Winslow, Herrington and Gagge,[3] demonstrated that the physical regulation, through constriction or dilatation of blood vessels, is due essentially to a change in conductivity over the gradient between environmental and internal body temperatures. That various portions of the body play relatively different rôles in the elimination of heat from the body, and that increasing environmental temperature or increasing heat production causes a much greater shift of blood to the extremities than to other segments of the body, was shown by Maddock and Coller,[4, 5] and Sheard and Herrick.[6] The results of further investigations regarding the dependence of the dissipation of heat from the body, in the zone of body cooling, on the state of dilatation of the peripheral blood vessels and the relative rôles of the upper and lower extremities in the control of heat elimination under environmental conditions ranging from 18 C to 32 C were previously presented in a paper[7] to this Society. It was pointed out that measurements of the skin temperatures of the fingers and toes serve as the most delicate and sensitive indicators of the changes in the vasomotor tone of the superficial blood vessels, in order that the rate of heat production may equal the rate of heat loss. Hick, Keeton and Glickman[8] extended these investigations through their study of the relationships between skin temperature and effective temperature scale (Houghten and Yagloglou[9]) and found that, in the zone of 66 to 72.5 deg ET, the control of loss of heat by radiation rests largely in the hands and that, in the higher range of 70 to 75 deg ET, it is largely in the feet.

In this contribution are presented: (1) the results of recent investigations on the changes in temperatures of the fingers and toes and the relative rôles of the upper and lower extremities in the dissipation of heat from the body, under various closely controlled environmental conditions which were changed in increments of 1 to 2 C within the range of 18 to 34 C; (2) the relationship between the temperatures of the toes and basal metabolic rates obtained at 25 C and 40 per cent relative humidity; (3) the effect of relative humidity with various atmospheric temperatures on the temperatures of the extremities, and (4) the cooling and warming rates of the toes in subjects with normal circulation. Comparisons of these data are made with the effects produced by increased production of heat and changes of environmental conditions on the skin temperatures of individuals with peripheral vascular disease.

Experimental Criteria

In order that significant and reproducible data may be obtained it is of importance that there be satisfactory regulation and control of: (1) the environmental conditions, (2) the person under test, and (3) the physical methods for measurement of skin temperatures. Details regarding the control of environmental temperatures and humidities, thermocouples, and the measurement of skin temperatures are given elsewhere.[10, 11] Air movement was confined to 15 to 30 fpm. The subjects wore lightweight pajamas or shorts and remained in the horizontal position on a comfortable bed during the period from 9 A.M. to 5 P.M. The necessity of an adequate period for adjustment of the body to any given temperature was

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***Associate, Section on Clinical Physiology, The Mayo Clinic.
†Consultant, Division of Medicine, The Mayo Clinic.

[1]The Application of the Theory of Heat Flow to the Study of Energy Metabolism, by A. C. Burton. (*Journal Nutrition*, 1936, *7*:497).

[2]A Study of the Average Temperature of the Tissues, of the Exchanges of Heat and Vasomotor Responses in Man by Means of a Bath Calorimeter, by A. C. Burton and H. C. Bazett. (*American Journal Physiology*, 1936, *117*:36).

[3]Physiological Reactions of the Human Body to Varying Environmental Temperatures, by C.-E. A. Winslow, L. P. Herrington and A. P. Gagge. (*American Journal Physiology*, 1937, *120*:1).

[4]The Rôle of the Extremities in the Dissipation of Heat, by W. G. Maddock and F. A. Coller. (*American Journal Physiology*, 1933, *106*:589).

[5]The Function of Peripheral Vasoconstriction, by F. A. Coller and W. G. Maddock. (*Annals of Surgery*, 1934, *100*:983).

[6]Changes in Surface and Rectal Temperatures in Man Produced by the Ingestion of Food Subsequent to Twenty-four Hour Fast, by J. F. Herrick and Charles Sheard. (*American Journal Physiology*, 1935, *113*:62).

[7]Investigations on the Exchanges of Energy Between the Body and Its Environment, by Charles Sheard, M. M. D. Williams and B. T. Horton. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, March, 1937, p. 189).

Presented at the 45th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1939.

[8]Physiologic Response of Man to Environmental Temperature, by F. K. Hick, R. W. Keeton and Nathaniel Glickman. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, March, 1938, p. 196).

[9]Determination of the Comfort Zone, by F. C. Houghten and C. P. Yagloglou. (ASHVE TRANSACTIONS, Vol. 29, 1923, p. 361).

[10]The Electromotive Thermometer: An Instrument and a Method for Measuring Intramural, Intravenous, Superficial and Cavity Temperatures, by Charles Sheard. (*American Journal Clinical Pathology*, 1939, *1*:209).

[11]Loc. Cit. See Note 7.

shown by Freeman and Lindner;[12] hence it is essential that the body remain under any given atmospheric condition for an hour or more, or until fairly constant readings of the extremities (particularly of the toes) are obtained. In an investigation on the effects of posture, Roth, Williams and Sheard[13] found that, under environmental temperatures ranging from 23 to 30 C, with a relative humidity of 40 per cent and the subject in the basal state and free from sweating of the extremities, the skin temperatures of the fingers and toes decreased when the extremities were elevated and increased when the extremities were pendent. Hence the maintenance of the subject in the horizontal position and the movement of bed, subject and thermocouples, as a unit, when it was necessary to change from one to another set of environmental conditions, have contributed greatly to the accuracy of the data which have been obtained.

Relationships of Skin Temperatures of the Normal Subject in the Basal State and Under Standard Environmental Conditions

In clinical investigations concerning functional (vasospastic) or organic (occlusive) involvement in either upper or lower extremities (or both) and the changes that may be produced by the administration of typhoid vaccine, by increased production of heat through the ingestion of food or by increases in atmospheric temperature, it is necessary to know the relative values of the superficial skin temperatures, particularly of the fingers and toes, of healthy individuals with normal basal metabolic rates, normal dryness of hands and feet, unclothed and in the horizontal position under certain standard environmental conditions. An atmospheric temperature of 25 C (77 F) and a 40 per cent relative humidity have been found to be satisfactory. Under these conditions, the skin temperatures of the forehead, thorax and extreme upper portions of the arms and legs are commensurate in value and lie within the range of 32 C (89.5 F) to 35 C (95 F), whereas there is a temperature gradient in the extremities, the toes showing the lowest temperature.

[12]Some Factors Determining the Variability of Skin Temperature, by H. Freeman and F. E. Lindner. (*Archives Internal Medicine*, 1934, *54*:981).

[13]Changes in the Skin Temperatures of the Extremities Produced by Changes in Posture, by G. M. Roth, M. M. D. Williams and Charles Sheard. (*American Journal Physiology*, 1938, *124*:161).

Table 1—Skin Temperatures of Selected Areas of the Body of Normal Subjects in the Basal State Under Environmental Temperatures Maintained at Various Degrees. (Relative Humidity, 40 Per Cent)[a]

Subject	Room Temperature		Range of Skin Temperature, C			
	F	C	Forehead	Leg (Above Knee)	Fingers	Toes
A	67.1	19.5	32.3—32.5	32.1—35.0	31.0—32.5	18.3—18.8
	69.8	21.0	33.0—33.4	30.9—32.0	31.9—35.0	20.4—23.1
	72.5	22.5	33.0—33.8	32.2—33.0	32.8—33.7	24.8—26.7
			32.4—33.6	31.9—32.3	33.9—34.2	22.8—27.2
	77.0	25.0	34.1—34.3	33.5—33.8	33.9—34.0	28.6—29.7
	78.8	26.0	33.3—33.7	33.6—34.0	34.3—36.2	31.4—32.2
	79.7	26.5	34.2—34.5	32.9—33.5	34.0—35.9	32.5—33.3
	83.3	28.5	34.6—35.0	—— ——	34.6—35.0	34.0—34.7
	93.2	34.0	35.6—36.3	34.8—35.2	34.3—36.3	35.1—35.6
B	64.5	18.0	32.7—33.0	29.4—31.7	24.0—28.1	17.3—17.8
	68.0	20.0	33.5—33.8	30.1—31.7	27.4—29.4	18.1—18.7
	68.9	20.5	34.2—34.7	31.3—32.9	31.0—35.1	19.2—20.1
	69.8	21.0	33.5—33.8	30.7—32.7	28.0—30.5	19.8—20.5
	72.5	22.5	33.6—33.9	31.1—32.8	33.0—34.3	21.0—21.4
	74.3	23.5	33.3—34.2	32.2—32.9	30.0—33.5	21.6—22.3
	76.1	24.5	34.1—34.3	30.9—33.9	33.1—34.7	23.6—29.0
			33.3—34.2	33.0—34.3	31.6—33.7	23.5—25.2
	77.0	25.0	35.0—35.3	32.8—33.6	35.3—36.0	28.4—30.1
	78.8	26.0	33.8—34.3	32.3—34.0	33.0—35.2	30.5—32.6
	84.2	29.0	34.5—35.1	33.4—33.9	34.8—35.7	32.7—33.6
	89.6	32.0	35.8—36.3	34.7—35.6	35.2—36.0	34.3—35.3

[a]The range of skin temperatures for any of the areas specified occurred during a period of observation of from four to six hours.

A representative set of data is shown in Fig. 1. In general the temperature of the toes will be slightly above room temperature. Ordinarily, the time-temperature relationships of all toes and fingers, per se, closely parallel each other, with possible temperature differences ranging between 1 and 2 C. The forehead, thorax and upper part of the legs are 7 to 10 C warmer than the toes and lie approximately within the range of 32 to 34 C. Since the temperature of the skin in any area is the resultant of the heat brought to it largely by its blood supply and the heat dissipated from its surface, there is a marked (but normal) vasoconstriction of the peripheral vessels of the feet, as is shown by the relatively low temperatures of the toes, which is operative to conserve the heat of the body. In contrast to this condition, however, there is evidence of considerable vasodilatation of the peripheral vessels of the fingers, and the finer adjustments or regulations of the dissipation of heat are controlled by the fingers and hands, as is shown by the fluctuating temperatures of the fingers.

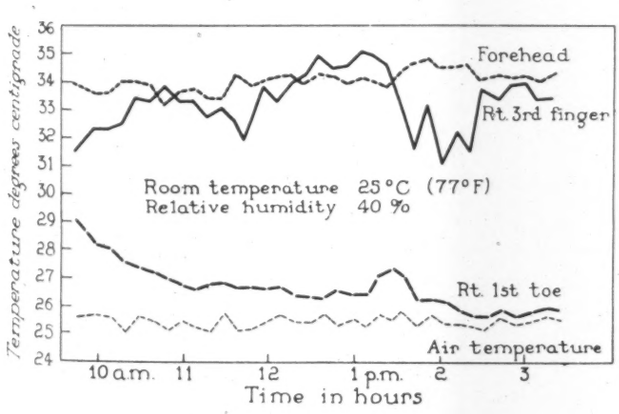


Fig. 1—**Curves of skin temperatures of forehead, finger and toe of a normal subject in the basal metabolic state in an environmental temperature of 77 F (24.5 C) and 40 per cent relative humidity**

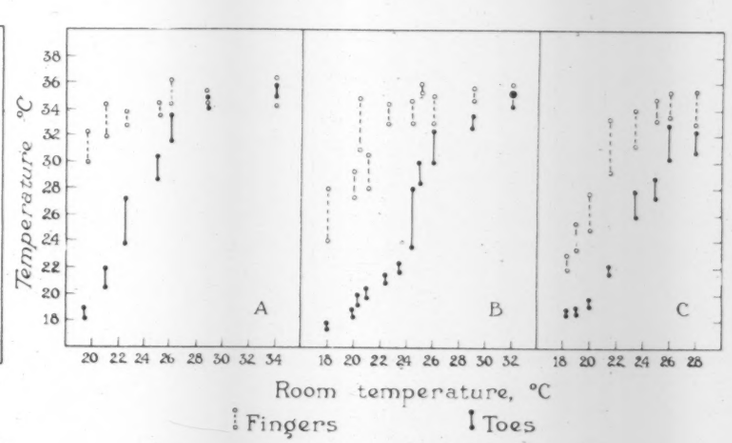


Fig. 2—**Curves showing the relative roles of the upper and lower extremities (as indicated by the skin temperatures of the fingers and toes) of normal subjects under a range of environmental temperatures extending from 18 to 34 C**

Table 2—Data Regarding the Skin Temperatures of the Fingers and Toes of Subjects Placed Under Specified Environmental Temperatures and Various Relative Humidities

Enviromental Conditions		Subject C		Subject D	
		Average Temperature, C		Average Temperature, C	
Dry-Bulb Temperature, F	Relative Humidity (Average Value) Per Cent	Fingers	Toes	Fingers	Toes
70	53	31.5	22.1	30.2	21.3
	76	28.4	23.3	26.5	22.4
72	40	28.5	22.5	26.5	22.1
	62	30.5	25.6	31.0	23.8
74	40	34.8	30.5	34.5	29.5
	54	32.0	25.4	31.7	24.4
	68	28.0	23.8	27.4	23.6
76	42	34.7	29.5	33.5	28.7
	54	34.0	29.3	33.8	28.8
	73	34.6	29.5	34.3	30.1
79	38	35.1	32.0	35.5	32.5
	50	35.0	32.6	35.1	32.7
	64	35.7	33.8	35.8	34.6
82	34	35.5	33.9	35.6	34.2
	53	35.7	34.3	36.1	34.0
	76	34.9	33.8	35.1	33.6

The temperatures of the toes under standard environmental conditions will be modified by the presence of moisture on the feet and by the rate of heat production. If the extremities are moist, the temperature of the toes may be below room temperature and remain so throughout the course of the day. This effect is doubtless due to the loss of heat by evaporation. This condition can be demonstrated in an individual with dry extremities by placing a film of water of the same temperature as the part of the foot to which it is applied and observing the subsequent reduction in the temperatures of the toes of the extremity involved. Furthermore, all other conditions remaining the same, the drying of a moist foot or hand will be followed by a rise in temperature.

Relative Rôle of the Extremities in Dissipation of Heat Under Various Environmental Conditions

The relative rôle of the upper and lower extremities, as indicated by measurements of skin temperatures of the fingers and toes, in the regulation of the dissipation of heat from the body has been investigated in several individuals with normal circulation under environmental temperatures which have been increased by increments of 1 to 2 C, the relative humidity remaining 40 per cent. Table 1 presents the data concerning the temperatures of the forehead, upper part of the leg, fingers and toes of two subjects systematically tested under room temperatures ranging from 18 C (64.5 F) to 34 C (93.2 F). The basal metabolic rates were 40.7 cal per square meter per hour for subject *A* and 36.4 cal per square meter per hour for subject *B*. The range of variation of temperatures for the four areas given in the table occurred in each instance during a period of four to six hours' exposure to the specified atmospheric temperature. The relationships between the temperatures of the toes and fingers and the room temperatures for three subjects of somewhat different basal metabolic rates are shown in Fig. 2.

Under environmental conditions ranging from 18 to 22 C the temperatures of the toes are, in general, at or near atmospheric temperature, whereas increased vasodilatation is occurring in the upper extremities as is indicated by the rise in temperature of the fingers. When the fingers reach temperatures of 33 to 35 C, indicating approximately maximal normal vasodilatation, the temperatures of the toes exceed the environmental temperature. This ordinarily occurs under a room temperature of 25 to 26 C. Further increase of environmental temperature produces little if any change in the temperatures of the fingers, whereas the temperatures of the toes increase rapidly and reach a value comparable to the temperatures of the fingers under an environmental temperature of 28 C (82.5 F) to 29 C (84 F). Hence, in normally reacting subjects, as the temperature of the room is increased, the regulation of the dissipation of heat is accomplished initially by the hands and lower portions of the arms (since normal vasoconstriction of the lower extremities is present). This is followed by a regulatory control on the part of the feet and lower portions of the legs when the room temperature reaches 25 C (77 F). Finally, at higher environmental temperatures (28 to 32 C), the temperatures of the fingers and toes closely approximate the temperature of the forehead, thorax, legs and arms. At atmospheric temperatures exceeding about 31 to 32 C, maximal vasodilatation of peripheral blood vessels will be maintained, and the internal temperature of the body will be kept approximately constant by changes in secretion of sweat in order to balance the heat received from the environment. In turn, passing through the indicated range of environmental temperatures, in which there is an increased loss of heat due to radiation plus convection and an increased positive storage or cooling of the body tissues (Winslow,[14] et al), and proceeding from the highest to the lowest temperature, it is found that the regulation of the loss of heat is accomplished initially by the lower extremities to the point at which the temperatures of the toes are at room temperature. This indicates normal vasoconstriction of the peripheral vessels of the extremities of the feet and a change in the gradient of vasoconstriction in the lower extremities. Whenever necessary, further regulation of the loss of heat is completed by vasoconstriction of the peripheral vessels of the upper extremities.

Effects of Changes of Atmospheric Humidity on Responses of Extremities

The relative humidity was maintained as near 40 per cent as possible throughout the previous series of tests regarding the relative rôles of the upper and lower extremities in the dissipation of heat from the body, as judged by the temperatures of the fingers and toes. It was of interest, therefore, to determine whether changes in relative humidity at any specified air temperature produced changes in the temperatures of the fingers and toes of two normal subjects with basal metabolic rates of 43.1 and 38.2 cal per square meter per hour. A range of air temperatures from 21 C (70 F) to 27.6 C (82 F) was chosen because the loss of heat due to evaporation is nearly constant and the subjects reported comfort except for some chilliness of feet at the lowest environmental temperature. The temperature of the forehead ranged from 33.2 to 34.6 C. The data recorded in Table 2 show that, within the range of normal variations of environ-

[14] Physiological Reactions and Sensations of Pleasantness Under Varying Atmospheric Conditions, by C.-E. A. Winslow, L. P. Herrington and A. P. Gagge. (ASHVE Journal Section, *Heating, Piping and Air Conditioning*, Jan., 1938, p. 69).

mental and skin temperatures, there is little if any effect of considerable changes in relative humidity at any given atmospheric temperature on the skin temperatures of the fingers and toes. Any minor increases in skin temperature which might be produced by large increases in atmospheric humidity are overshadowed by the relatively large thermal changes in the extremities due to small changes in environmental temperature.

Thermal Changes in the Extremities and Increased Production of Heat

1. *The Ingestion of Food.*—The changes in temperature of the fingers and/or toes and the relative rôles of the upper and lower extremities, under various environmental temperatures, in the dissipation of heat, in the event that an increased production of heat occurs, were considered previously. In order that data regarding the changes in skin temperature of a normal subject subsequent to the ingestion of food may be available for com-

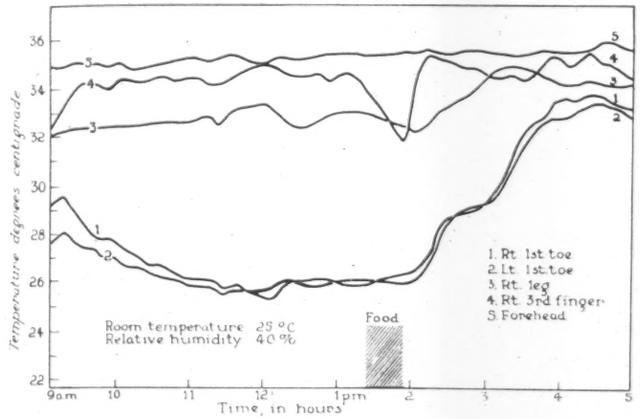


Fig. 3—Curves showing the time-temperature relationship of the forehead, upper leg, fingers and toes of a normal subject before and after the ingestion of food. Curves 1 and 2, indicating the temperatures of the toes, show the role of the lower extremities in the dissipation subsequent to the increase in heat production when the subject is in an atmospheric temperature of 25 C

parison with the results obtained for persons with peripheral vascular disease, the records shown in Fig. 3 are included. The data plotted in the left-hand portion (from 9 A. M. to 1 P. M.) show that, in a person in the basal state and in an atmospheric temperature of 25 C, the temperatures of the fingers and forehead were respectively approximately 34 to 35 C, whereas the toes were near room temperature. These skin temperatures are indicators of approximately maximal peripheral vasodilatation in the upper extremities with normal vasoconstriction in the feet and lower part of the legs. Hence the regulation of the elimination of heat should be assumed by the lower extremities in the event that the production of heat is increased and the thermal changes of the toes should vary somewhat commensurately with changes in the rate of heat production. This is shown by the considerable rise in temperature of the toes (from 26 C to 33 C) in the course of three hours after the ingestion of a standard meal.

2. *Relationship Between Basal Metabolic Rates and Temperatures of the Toes.*—Maddock and Coller[15] concluded that the close connection between the temperature of the extremities and the mechanism for the dissipation of heat is shown by the fact that, under constant environmental conditions, a simple linear relationship is found between the temperature of the great toes and the basal heat production per unit of surface area. The experimental data on which this conclusion is based are meager and open to some criticism. The results of the authors' findings for a small group of normal subjects are shown in Fig. 4. There is a rather wide scattering of points, but there is evidence to show that there is an approximately linear relationship of a dual character existing between the average temperatures of the toes and the basal metabolic rates obtained under environmental conditions of 25 C and 40 per cent relative humidity. The two lines of linear relationship are roughly parallel to each other. This twofold relationship cannot be explained, since there is no connection between sex (all subjects were males), season of the year, or other factors of this character. However, the type (slender or stout) of the individual and the presence of sweat on the extremities, or normally dry feet and hands as the case may be, may afford some possible explanation.

Cooling and Warming Rates of the Toes

When the normal subject in the basal state is moved from an environment of 26 C (79 F) to an environment of 18 C (65 F), there is relatively little thermal change

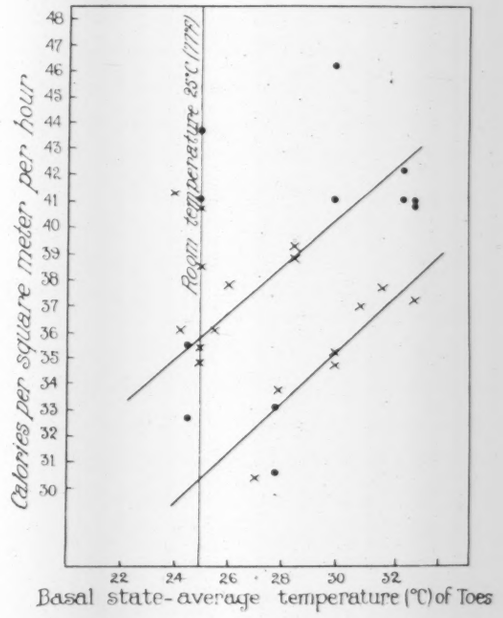


Fig. 4—The relationships between the average temperatures of the toes of a group of normal subjects and the basal metabolic rates. The atmospheric conditions were maintained constant at 25 C and 40 per cent relative humidity

in the forehead, thorax, arms and upper portions of the legs. In contrast, there is definite cooling of the toes, and constancy of temperature (approximately that of the room) is reached in about an hour. In turn, when the subject is moved from a room at 18 C to an environment of 34.5 C (94 F), the changes in temperature are again

[15] Loc. Cit. See Notes 4 and 5.

most pronounced in the toes. The rise in temperature is rapid at first; this is followed by a gradual change as the temperature of the toes approximates a maximal value of about 35 C. Curve 1 in Fig. 5 gives representative data regarding the cooling and warming of the toes under the two specified environmental conditions.

If Newton's law of cooling is applicable, then the rate of cooling or warming of the tissue should be proportional to the difference between the temperature of the tissue and its surroundings. The relationship may be written as an exponent function:

$$T_t = T_o e^{-at}$$

in which T_o is the initial (zero time) difference in temperature, T_t is the difference in temperature at any specified time, t, and a is the constant. It follows that:

$$a = \frac{1}{t} \log_e \frac{T_o}{T_t}$$

If data such as those given in Fig. 5 are plotted on semi-logarithmic paper, the ordinate being the difference between the temperature of the skin and of the room at any given time, t, indicated as the abscissae, there should be a straight line if the rate is a constant. If there is a change in the rate of cooling or warming of the extremities (toes) of individuals having normal circulation, there should be corresponding changes in the slopes of the lines representing the relationship between the difference of temperatures and the time.

The data plotted in Fig. 6 show that the range of rates of cooling of the toes in normal subjects was between 0.02 and 0.05 C per minute. Similar rates were found for persons with peripheral vascular disease. Since rates of cooling are found to lie within the same range in either normal or abnormal circulatory conditions of the feet, it follows that corresponding changes are present in the supply of blood due to peripheral vasoconstriction and that the same order of change exists in the temperature gradient between the deeper and superficial tissues in all cases. Hence, to the first order of approximation, the rates of cooling of the toes are the same in either normal circulatory conditions or in peripheral vascular diseases, since vasoconstriction, whether spastic or obstructive in character, is operative in all instances.

The data obtained concerning the rates of warming of the toes, as illustrated in Fig. 7, show that there are two (and possibly three) distinct rates falling within the range of 0.015 to 0.15 C per minute. The initial rates of warming lie between 0.015 and 0.030 C per minute and are constant, per se, until the temperatures of the toes reach a value of approximately 28 C. A definite change in the rates of warming, ranging in normal circulatory conditions from 0.04 to 0.10 C per minute, occurs at a temperature of about 27 or 28 C. This indicates that there is an increase in the supply of blood to the periphery brought about by vasodilatation of the vessels. Hence there are two distinct values for the rates of warming: the initial value represents the rate of environmental heating of the tissue only, whereas the second rate indicates the combined effects of the heating of tissue by the environment and the increased blood supply. The fact that a change of rate is definitely indicated in the rate of warming at an environmental temperature of about 28 C is in accord with the findings which have been presented regarding the regulatory control of the dissipation of heat, which is assumed initially by the

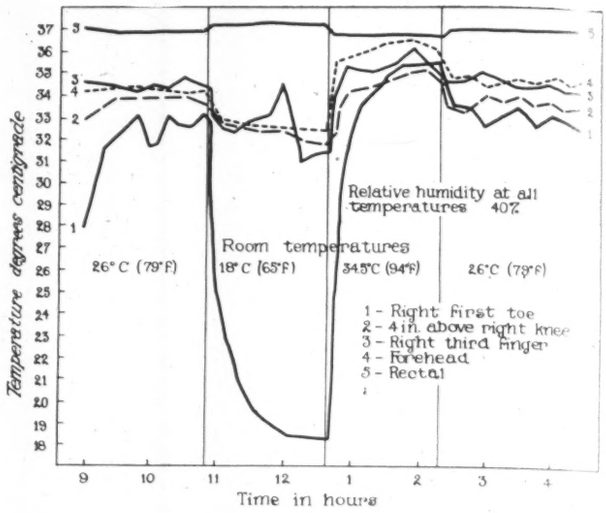

Temperature degrees centigrade
Relative humidity at all temperatures 40%
Room temperatures
26° C (79° F)
18° C (65° F)
34.5° C (94° F)
26° C (79° F)
1 - Right first toe
2 - 4 in. above right knee
3 - Right third finger
4 - Forehead
5 - Rectal
Time in hours

Fig. 5—Curves showing the changes in skin temperatures produced in various regions of the body when the subject was moved from an atmosphere of 26 C to cooler or warmer environmental temperatures. Curve 1 indicates that the chief vasomotor responses are in the lower extremities

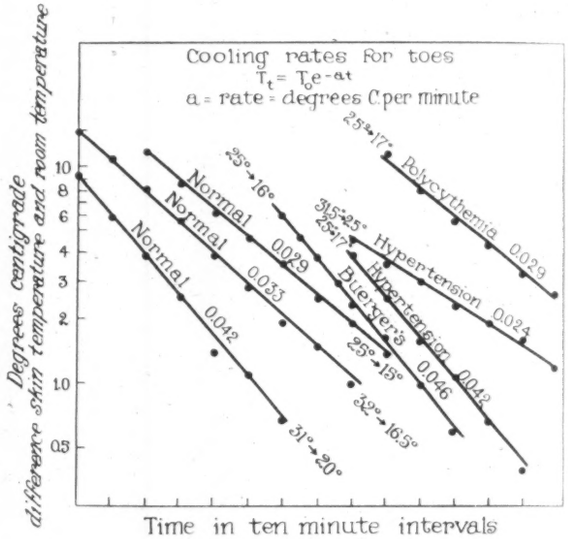


Fig. 6—Cooling rates of the toes of individuals with normal circulation and in cases of peripheral vascular disease

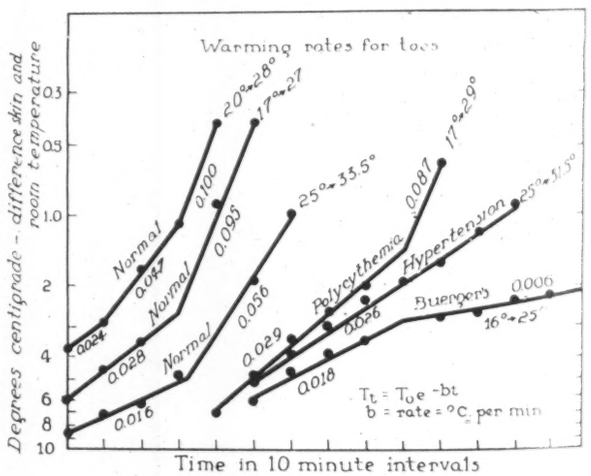


Fig. 7—Rates of warming of the toes of normal subjects and in cases of peripheral vascular disease

lower extremities when the temperatures of the toes are 24 to 26 C.

If abnormal vasoconstriction (spasm) or organic occlusion is present, the rates of warming of the tissue due to the absorption of heat from the environment will be approximately the same as in normal circulation, but there will be abnormally low or possibly decreased rates of warming in the range of environmental temperature in which vasodilatation normally occurs.

Skin Temperatures of Extremities in Peripheral Vascular Diseases

Consideration has been given in some detail in the preceding paragraphs to the important rôle of the extremities, as indicated by measurements of the skin temperatures of the fingers and toes of subjects with normal circulation and vasomotor control, in the dissipation of heat from the body under various atmospheric and physiologic conditions. An increase or decrease of superficial temperature is indicative of a corresponding change in the supply of blood to the peripheral tissues. Since changes in the blood supply are controlled chiefly by vasoconstriction or vasodilatation of the blood vessels, it follows that the marked regulation of the dissipation of heat, in the zone of body cooling, is accomplished by an equally marked and varying degree of peripheral vasoconstriction, or vasodilatation as the case may be.

A comparison of the data and information which have been obtained regarding the regulatory function of the extremities in the dissipation of heat with the findings in peripheral vascular disease is, obviously, of considerable importance to the medical profession from the standpoint of diagnosis and treatment. These data are of significance to the heating and ventilating engineering profession because of the fact that, under certain environmental conditions, release of abnormal vasoconstriction and a betterment of circulatory conditions may be accomplished, in some measure at least, in many individuals as well as affording added comfort and efficiency.

In general terms, peripheral vascular deficiencies may be classified in three main groups: (1) organic occlusion only, with little or no spasm, as in advanced cases of thrombo-angiitis obliterans (Buerger's disease); (2) pure spasm with no organic obstruction, as in Raynaud's disease, and (3) some organic occlusion and a variable degree of vasoconstriction. In these individuals, as in normals, the processes of dissipation of heat should occur with a limitation, which is imposed by reason of the inability of the blood vessels to contract or to dilate. The restriction thus imposed may vary considerably in its degree and location in various peripheral vascular diseases. Considerable information regarding the character of the involvement may be acquired from studies of the skin temperatures of the extremities under various environmental conditions.

Sets of data regarding the skin temperatures of the fingers and toes in conditions of essential hypertension, Raynaud's disease and Buerger's disease, are given in Figs. 8, 9 and 10. Since the degree of vasospasm, occlusion, or a combination of both factors varies considerably in different individuals with peripheral vascular disease, the data shown in the curves should be considered only as illustrative of the marked differences in findings which occur in these cases, when compared with the skin temperatures of normal subjects under corresponding environmental conditions.

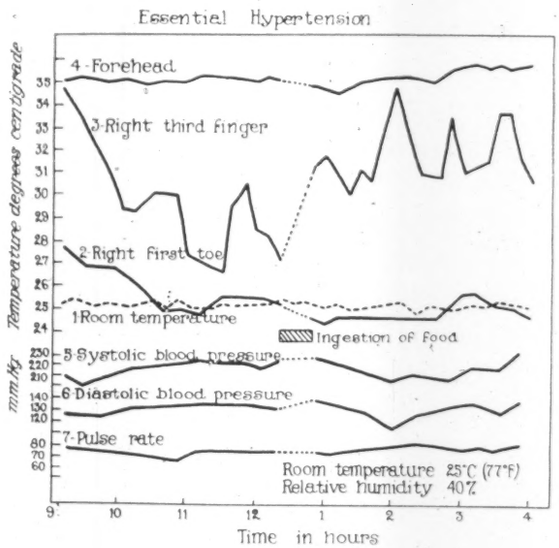


Fig. 8—Curves showing the time-temperature relationships of the fingers and toes of an individual with essential hypertension. The temperatures of the fingers and toes indicate abnormal vasoconstriction in an atmosphere of 78 F

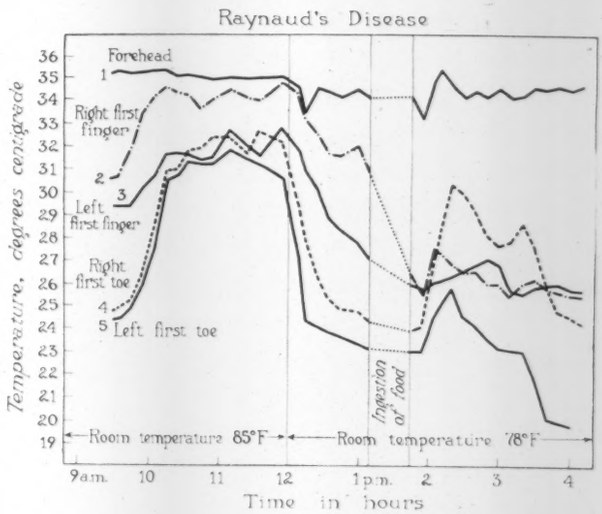


Fig. 9—Curves showing the effects of environmental temperature on the skin temperatures of the toes and fingers in Raynaud's disease. There is marked vasoconstriction of the fingers in an environment of 78 F which is replaced by a considerable degree of vasodilatation in an environment of 85 F

Essential Hypertension. In the case of an individual with essential hypertension (Fig. 8) and a blood pressure of 220/130 mm of mercury, there is abnormal vasoconstriction of both extremities as is evidenced by the fact that the skin temperatures of the fingers are low and fluctuate considerably. Following the ingestion of food, the temperatures of the toes remain at room temperature with some rise in, but spasmodic control of, the temperatures of the fingers. In an individual of this type there

will be considerable vasodilatation of the extremities when the environmental temperature is raised from 29 to 31 C. Under these atmospheric conditions the temperatures of the fingers approximate those obtained with normal individuals and there will be considerable vasodilatation of the lower extremities, although the temperatures of the toes may be several degrees below the normal findings in corresponding air temperatures.

Raynaud's Disease. As is shown in Fig. 9, the temperatures of the toes are a degree or so above atmospheric temperature (30 C). The temperatures of the fingers, particularly of the left hand, are from 1 to 3 deg below the temperature of the forehead. Under similar environmental conditions a normal person exhibits skin temperatures of approximately 35 C for the fingers, toes, thorax and forehead. After placing the subject in an environmental temperature of 25 C, there is a drop in the temperatures of the fingers and toes to values which are much lower than normal. The subsequent ingestion of food shows a rise in the temperatures of the toes, whereas the fingers remain at a temperature slightly above that of the room.

Buerger's Disease. The curves of Fig. 10 show that the temperatures of the fingers and forehead are commensurate (34 to 35 C), whereas the toes are at or slightly below room temperature when in the steady state. Following the ingestion of food there is a rise of 3 C in the temperature of the toes of the left foot as compared with a rise of about 7 C in the toes of the right foot. It is apparent that the degree of involvement is much greater in the left lower extremity. In general, it has been found that the increases in the temperatures of the toes in cases of Buerger's disease following the ingestion of food are practically the same as those obtained after the administration of typhoid vaccine, if allowance is made for the rise of rectal temperature produced by the vaccine.

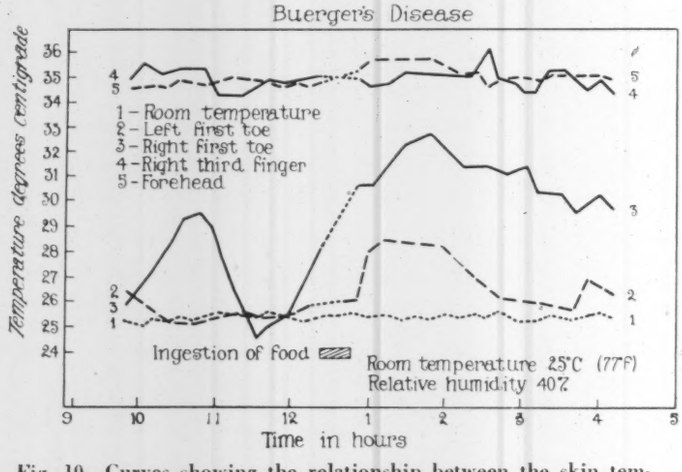


Fig. 10—Curves showing the relationship between the skin temperatures of the fingers and toes in a case of Buerger's disease. Curves 2 and 3 show that involvement in the left lower extremity is greater than in the right one

Vasospasm and Environmental Conditions. As has been suggested in the foregoing considerations, it is possible to determine the environmental temperatures at which the extremities, in cases of peripheral vascular disease, exhibit some degree of vasodilatation. Pickering and Hess[16] stated that they encountered no subjects, normal or diseased, in whom warming the body failed to produce a vasodilator response in the fingers unless the sympathetic nerves were divided or the vessels structurally diseased. Their observations also indicated that warming the body removes only a part of the vasoconstriction tone from the feet, the remainder being more or less permanent. In general, the results of the present investigations are in accord with the conclusions of Pickering and Hess.

In many instances of peripheral vascular disease, the extremities are moist and cool to the touch, and the subjects complain of cold hands or feet, as the case may be. When a marked degree of vasospasm is present, thereby interfering with the normal control of the loss of heat through the vasomotor regulation of the peripheral blood supply, it is probable that the dissipation of heat is accomplished by the evaporation of sweat which is present in abnormal amounts. As a result of the vasospasm and the abnormally high degree of evaporative regulation, which are present under environmental conditions that normally call for dissipation of heat chiefly by the processes of radiation and convection, the temperatures of the toes may be several degrees Centigrade below room temperature (25 C). The temperatures of the fingers may range from normal values (32 to 34 C) to temperatures indicative of pronounced vasoconstriction of the peripheral vessels of the upper extremities. As the atmospheric temperatures are progressively increased, environmental conditions may be found in which considerable dilatation of the peripheral vessels occurs in functional vasospasm. In general, there will be corresponding changes in the temperatures of the toes which are commensurate with the values found in normal subjects, although conditions are encountered in which there is evidence of tissue heating only, with little vasodilatation of blood vessels. In organic occlusion of the lower extremities, with some superimposed spasm, environmental temperatures may be established in which the lower extremities will be normally dry and in which the temperatures of the toes will be above the atmospheric temperature, thereby indicating increased blood supply. This range of atmospheric conditions varies with the degree of vasospasm and occlusion, but may be set at from 28 C (82 F) to 32 C (90 F).

[16]Vasodilatation in the Hands and Feet in Response to Warming the Body, by G. W. Pickering and W. Hess. (*Clinical Science*, 1935, 1:213).

Research Executive Committee Meets

At a meeting of the Research Executive Committee held in New York on April 19 plans were formulated for the collection of additional funds to defray the cost of special studies approved by the Committee. One of these projects involves the erection of two test cubicles for determining the heat flow through various types of wall construction with various summer and winter weather conditions.

Progress reports were reviewed covering the Research projects being investigated at the various cooperating institutions. Possible cooperation with the Air Conditioning Committee of the Edison Electric Institute was considered and general approval was given to the initiation of tests to be conducted at the Pittsburgh Laboratory on human reactions to color sensations in various environmental conditions.

Members in attendance included W. L. Fleisher, Chairman; J. H. Walker, Vice-Chairman; C.-E. A. Winslow, Technical Adviser; A. E. Stacey, Jr., T. H. Urdahl, J. H. Van Alsburg, Director F. C. Houghten, John James, Technical Secretary, and by invitation Dr. Leonard Greenburg.

CORRELATING THERMAL RESEARCH

As a part of the efforts of the ASHVE Research Laboratory to correlate research in thermal engineering carried on by the many institutions engaged in such work, and to disseminate the published results of such studies together with other reports of progress in the field, and in order to make this information available to the membership of the Society, there is published monthly on this page a limited number of brief abstracts of articles which it is believed will be of interest to all concerned. For more complete lists address the Librarian, ASHVE Research Laboratory, U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa.

F. C. Houghten, *Director*.

W. L. Fleisher, *Chairman*
COMMITTEE ON RESEARCH

A Simplified Pitot-tube Traverse, by T. K. Sherwood and G. T. Skaperdas. *Mechanical Engineering*, Vol. 61, No. 1, Jan. 1939, pp. 22-23. By using the Gauss method of numerical integration of the formula based on a single traverse, the total flow in a pipe may be computed from three or four selected Pitot measurements. Comparison of graphical integration and ten point method with these two Gauss methods shows the simpler method has an average error under 1.1 per cent of graphical integration computation. Gauss method gives results sufficiently accurate for plant tests.

•

A Magnetic Flowmeter, by W. M. Lansford. *Mechanical Engineering*, Vol. 61, No. 1, Jan. 1939, pp. 20-21. Description of a new magnetic flowmeter to determine rate of flow of fluid inside a pipe. A bar magnet is suspended by one end, inside a non-magnetic length of horizontal pipe. A balanced magnetized steel needle is placed outside the pipe in such a position that it will indicate the deflection of the magnet inside the pipe. Table shows the relation of velocity of water to deflection of the needle.

•

The Law of Air Flow in a Laboratory Pipe System with Natural Ventilation, by F. B. Hinsley. *Colliery Engineering*, Vol. 16, No. 180, Feb. 1939, pp. 65-66. Report of laboratory investigation into natural ventilation in a pipe system. Quantity measurement of air flow in a pipe due to natural ventilation.

•

Sterilizing Air with Ultra-violet Rays, by Frederic W. Robinson. *Heating and Ventilating*, Vol. 36, No. 2, Feb. 1939, p. 24. Discussion of air sanitation and its need in hospital operating rooms, and the preservation of food. Use of ultra-violet light to sterilize air in intake ducts and in direct use in a room, in connection with air conditioning systems.

•

Operating Methods in Air Conditioning, by Tony J. Vollman. *Ice and Refrigeration*, Vol. 96, No. 2, Feb. 1939, pp. 114-116. Discussion of the care and maintenance of air conditioning equipment. Cost data of operation of air conditioning equipment in the Field Building, Chicago, a modern office building.

•

Friction Losses in Asbestos Prefabricated Ducts. *Heating and Ventilating*, Vol. 36, No. 2, Feb. 1939, pp. 39-40. Prefabricated ducts made of asbestos are now available in either round or rectangular cross-sections and their frictional properties have been tested at the Mellon Institute of Industrial Research. Method of taking tests and friction chart.

•

Forced Draft for Underfeed Stoker, by J. R. Darnell. *Power Plant Engineering*, Vol. XLIII, No. 2, Feb. 1939, pp. 111-112. Duct characteristics or system resistance should be studied carefully in any particular installation in connection with the operation of underfeed stokers with mechanical draft fans.

•

Combustion in Small Underfeed Stokers, by C. A. Barnes. *Power Plant Engineering*, Vol. XLIII, No. 2, Feb. 1939, pp. 114-116. Report of tests on the process of combustion in a typical small underfeed stoker. Conducted at Battelle Memorial Institute, sponsored jointly by Bituminous Coal Research Inc. and the Institute. Fuel bed temperatures charted.

•

The Prediction of Noise Levels from Mechanical Equipment, by John S. Parkinson. *Heating and Ventilating*, Vol. 36, No. 3, March 1939, pp. 23-26. Sound levels are important in some air heating and cooling installations. The equipment installed should not add to the noise. The author indicates how certain sound level problems can be solved and how the sound level can be reduced to a desired point in certain instances.

•

A Handbook on Ventilation Including Air Conditioning, by Percy L. Marks. Published by the Technical Press, Ltd., London, 1938; 138 pages, 63 illustrations, 5½ by 8½ in. A general handbook on the subject.

•

Data on Heat Output of Poultry Result from Government Research, by H. G. Barott. *Heating and Ventilating*, Vol. 36, No. 3, March 1939, pp. 27-29. Discussion of work done at the Animal Nutrition Division of the Bureau of Animal Industry with a respiration calorimeter laboratory located at the Agricultural Research Center, Beltsville, Md. The laboratory is equipped to determine the metabolic processes, and therefore the effect of environmental conditions and the feeding of different foodstuffs, on heat elimination and gaseous exchange.

•

Timber Drying, by R. G. Bateson. Published by Crosby Lockwood & Son, Ltd., London, 1938; 138 pages, 28 illustrations. Discussion of methods of drying timber in open air and in kilns, behavior of timber in use. Tables give correct temperatures and drying humidities for drying most timber.

•

The Selection of Centrifugal Fans, by J. F. Grocott. *The Journal of the Institution of Heating and Ventilating Engineers*, Vol. 6, No. 72, Feb. 1939, pp. 645-657. Discussion of various types of fans and their characteristics and some practical features concerning general selection.

•

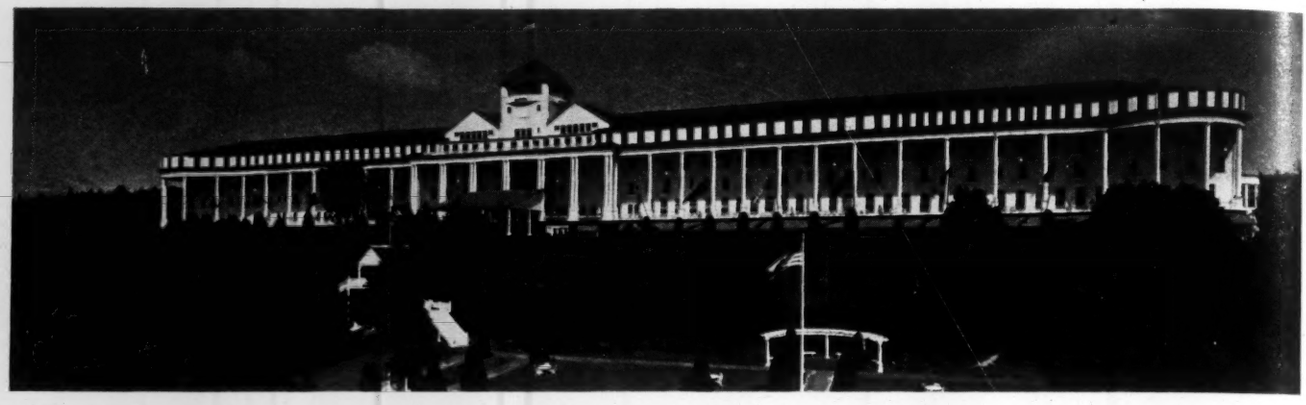
Discussion on Heating Sources for Installations Requiring 20 Million British Thermal Units Per Hour and Over, by J. MacIntyre and D. A. Grant. *The Institute of Fuel*, Vol. XII, No. 63, Feb. 1939, pp. 152-158. Discussion of use of various kinds of fuel on basis of smoke prevention and grit elimination from air; also initial and operating cost.

•

Properties of Glass, by George W. Morey. *American Chemical Monograph Series*. Reinhold Publishing Corp., New York, 1938; 561 pages. Thorough discussion of the properties of glass including a brief treatise on heat conductivity and heat capacity.

•

The Reactions of the Clothed Body to Variations in Atmospheric Humidity, by C.-E. A. Winslow, L. P. Herrington and A. P. Gagge. *The American Journal of Physiology*, Vol. 124, No. 3, Dec. 1938, pp. 692-703. Report of tests on physiological reactions of clothed human subjects in which air and wall temperatures were identical with each other but were varied over a wide range, with simultaneous variations in relative humidity. Bibliography.



Grand Hotel

Make Plans for Mackinac Now

THIS year the Great Lakes Summer Meeting at Mackinac Island, Mich., will be the main attraction for Society members and it will provide technical sessions of great educational value as well as a vacation trip in territory that offers much of historical interest.

No matter how you go (whether by boat, motor or train) Mackinac will be a revelation—an island paradise in Northern Michigan with every facility for enjoyment.

The Committee on Arrangements has planned an entertaining program for July 4 to 6 at the Grand Hotel. W. G. Boales, General Chairman, advises that the finishing touches will be completed at a final meeting of the committee to be held May 13 in Holland, Mich.

At Mackinac you will enjoy a return to the horse and buggy days as this mode of travel is used almost exclusively and accounts for the custom of calling this unique island The Bermuda of the North. Bicycles are also popular and those who try the iron steeds will find the winding roads of Mackinac delightful.

Michigan has excellent roads to Mackinaw City and motorists from the south and west may come through Chicago, those from the northwest will find it convenient to come via Duluth, St. Ignace, etc., and from the south and east, via Toledo and Detroit. Members will receive motoring information by mail with ferry schedules to Mackinac Island from various points.

Train service to Mackinaw City is provided by the Pennsylvania and New York Central railroads; over night from Grand Rapids, Chicago, Detroit, Cleveland, Buffalo, Cincinnati and Indianapolis. Typical train schedules and round trip railroad and Pullman fares are as follows:

Lv. Cincinnati	4:55 p.m.
Arr. Mackinac Island	10:00 a.m.
Round trip	$27.95
Pullman	7.90
Lv. Chicago	6:00 p.m.
Arr. Mackinac Island	10:00 a.m.
Round trip	$17.70
Pullman	6.30
Lv. Detroit	11:00 p.m.
Arr. Mackinac Island	10:00 a.m.
Round trip	$16.30
Pullman	5.30

Air cooled Pullmans are in service and special round trip rates are in effect from June 1 with a 30 day return limit.

Ferry service to Mackinac Island is maintained on a half-hour schedule from both Mackinaw City and St. Ignace. The running time is about 20 minutes by cruiser service. The fare from Mackinaw City is $1.00 round trip and from St. Ignace 75 cents. The hotel bus transports guests from the pier to the hotel for 25 cents per person.

For those who motor garage facilities are available at Mackinaw City and St. Ignace. Garage attendants will drive you to the ferry, give you a claim check and upon return will meet you at the dock. The storage charge is 50 cents per night.

Direct steamer service to Mackinac Island is maintained by the Chicago, Duluth and Georgian Bay Line from Buffalo, Cleveland, Detroit and Chicago, with the steamers *North American* and *South American*. These oil burning ships have outside state-

C. R. McConner

W. G. Boales

F. J. Linsenmeyer

Mackinac Harbor

rooms and will be popular with those who want a combined holiday and business trip.

Designed especially for passenger cruise service, every possible provision is made for amusement and recreation on the observation deck, promenade deck, lounge, library, veranda cafe, etc. Rates include stateroom and meals.

Headquarters for the Society's meeting will be the Grand Hotel, which is an island landmark visible long before the steamer docks. It stands on an elevation overlooking the Straits of Mackinac. Its imposing colonial porch is world famous and from it one sees beautiful gardens and the blue waters of the Straits.

Technical sessions will be held in the Casino and nine papers have been selected by the Meeting's Committee for presentation.

Among the subjects selected by the Meetings Committee for discussion are the following: Results of Comfort Studies at the Federal Reserve Building in Washington, D. C., and Metropolitan Life Insurance Building in New York; Performance of Cooling Towers; Performance of Convectors; Heating Low Cost Homes; and Theory of Transfer of Vapor through Walls.

Mackinac Street Scene

The entertainment features at Mackinac, planned by the Committee on Arrangements appointed by the presidents of the Michigan and Western Michigan Chapters, will be directed by O. D. Marshall of Grand Rapids. The general chairman, W. G. Boales of Detroit, has announced that Tom Brown, Chicago, and Frank Feely, Detroit, will be in charge of the events on the *North American* and *South American*, respectively. When technical and committee meetings are not in session, members will find many recreation features at their disposal without charge—among which are archery, badminton, croquet, ping pong, quoits, shuffleboard, swimming and tennis. Other features are service of bouillon in the forenoon and afternoon tea in the parlors and on the porch. There will be concerts and dinner music. Points of interest are village curio shops, Fort Holmes and Fort Mackinac Museum, National Park, and Yacht Pier. There are admission charges for the Church Mission, Japanese Gardens, John Jacob Astor House, and a charge is made for State Park carriage drive, rolling chairs, speed boats, saddle horses, and golf.

There will be something to do at Mackinac for every member of the family. Early reservations should be made as train, boat and hotel facilities will be in demand over July 4.

E. Holt Gurney Chairman of Ontario Research Foundation

E. Holt Gurney

By a recent Order-in-Council of the Government of the Province of Ontario, E. Holt Gurney, past president of the ASHVE, was named chairman of the Ontario Research Foundation to succeed Sir Joseph Flavelle, Bart., deceased. Mr. Gurney has been a member of the Advisory Council of the Ontario Research Foundation since it was created in 1928, and has been vice-chairman since 1932.

The Ontario Research Foundation was established at the instigation of the Prime Minister of the Province and an endowment fund, now standing at approximately $3,500,000, was created from subscriptions made over a period of five years from manufacturers, corporations and private individuals and from contributions from the Provincial Government on a dollar-for-dollar basis. The offices and laboratories are situated in Queen's Park, Toronto, in buildings set aside by the Government.

The Chairman has control and direction of the administration of the Foundation and reports yearly to the Lieutenant-Governor in Council, the report being tabled in the Legislature and published by the Government as a sessional paper.

Researches have been carried out for the benefit of industry and agriculture and to develop the natural resources of the Province. The main divisions of the Foundation are Engineering and Metallurgy, Chemistry, Textiles, Pathology and Bacteriology, Bio-chemistry and Agriculture. In most of these divisions fellowships have been maintained by manufacturing concerns in the Province.

The Foundation has been very active in the field of metallurgical research and investigation and has, through the Department of Engineering and Metallurgy, cooperated with the Society in investigations into the cooling requirements for summer comfort air conditioning in Toronto.

NEWS OF LOCAL CHAPTERS

National Society Night at Michigan Chapter

March 6, 1939. The March meeting of Michigan Chapter was National Society Night and J. F. McIntire, president of the ASHVE, J. H. Walker, vice-chairman of the Committee on Research, and F. C. Houghten, director of the Research Laboratory, were the featured speakers.

President McIntire spoke briefly on the history of the Michigan Chapter and also gave a short resumé of the history of the air conditioning industry. Mr. Walker discussed the cooperative research being undertaken under the direction of the Committee on Research. He stated that at the present time 12 universities are cooperating with the Research Laboratory.

Mr. Houghten discussed the subject of Physiological Response to Atmospheric Environment. He outlined the development of the effective temperature lines on the comfort chart and the effect that atmospheric conditions have upon the heat loss of the body by radiation and convection. He also discussed the effect of surrounding air conditions on the leucocyte blood count in the human body.

Pres. F. J. Linsenmeyer invited the past presidents of the Chapter to attend and the following were present at the meeting: E. M. Harrigan, F. W. Johnson, J. F. McIntire, E. E. Dubry, H. E. Paetz, L. L. McConachie, G. D. Winans, R. K. Milward and F. J. Feely.

Secy. G. H. Tuttle reports that the meeting adjourned at 10:00 p.m. with everybody giving a rising vote of thanks to Mr. Houghten.

Fan and Blower Testing Interests Southern California Members

March 14, 1939. The regular meeting of Southern California Chapter was preceded by an informal gathering at the Utility Fan Co., Los Angeles, which was for the purpose of a conducted tour through this interesting plant, where evaporative desert coolers are manufactured. Following this, a trip was made to the Elks Club of Pasadena, where the regular dinner meeting was held under the auspices of the Chapter.

During the business meeting, ways and means were evolved and put into motion to raise funds for the purpose of reimbursing the treasury for the expenditure of sending out meeting notices, etc.

Secy. A. J. Hess read minutes of the past meeting and the treasurer's report was given.

Announcement was made by the chairman of the Program Committee that April 11 would be President's night, when J. F. McIntire of Detroit would be the guest speaker at the Colonial Banquet Room in Los Angeles.

Upon motion, seconded and carried, the membership decided to assist the research work now being carried on at the University of California at Berkeley on cooling towers, and a committee was appointed by Pres. H. M. Hendrickson.

It was the decision of the meeting to invite the ASHVE to Los Angeles for the 1940 Semi-Annual Meeting, attempting to coordinate the time of this meeting with that of the *American Society of Refrigerating Engineers.*

The routine business was followed by an interesting discussion of fans and blowers, by R. T. Knapp of California Institute of Technology, regarding testing technique and characteristics found on testing certain fans and blowers. This discussion was interesting as well as practical, and the interest of the membership in the talk was clearly shown by the fact that it was only with reluctance that Dr. Knapp was allowed to close his discourse. Following the lecture, a trip was made through the California Institute of Technology's Fan Testing Laboratory, which had been set up for the purpose of testing locally made fans.

Philadelphia Chapter Discusses Underwriters' Rules

March 9, 1939. Philadelphia Chapter members and guests met at the Engineers Club and the minutes of the previous meeting and the treasurer's report were read and approved.

Edwin Elliot reported that an application for membership had been received from E. L. Wildman, S. A. Jellett Co.

R. F. Hunger announced that the April meeting would be an inspection of a large industrial plant, providing that satisfactory arrangements could be made. He also spoke of the annual golf outing to be held in May at the new St. David's Country Club.

A resumé of the work of the Year Book Committee was given by P. L. Pryibil.

L. P. Hynes offered a resolution on the death of Warren Webster, Sr. It was moved and seconded that the resolution be inscribed in the records and that a copy be sent to Mr. Webster's family.

M. F. Blankin presented the report of the committee to consider incorporation of the Philadelphia Chapter, ASHVE. The committee considered incorporation to be desirable but stressed the fact that the cost was rather high, about $300.00. The Committee thought that this expenditure might be offset by discontinuing the one dollar discount for prompt payment of dues for the next three years. It was moved and seconded that the Chapter be incorporated and that the prompt payment discount on Chapter dues be discontinued for a period of three years. The motion for incorporation was passed with 21 members voting for incorporation and 16 against it.

Mr. Blankin's committee was reappointed and requested to negotiate the incorporation.

Pres. H. H. Erickson then presented H. J. Knowles, American Air Filter Co., who discussed Recent Developments in Air Cleaning Apparatus. Mr. Knowles gave a very interesting and comprehensive discussion of the subject.

Following Mr. Knowles' talk, President Erickson presented the suggested ordinance Governing the Installation of Air Conditioning, Warm Air Heating, Air Cooling and Ventilating Systems, Employing Ducts. Secy. H. H. Mather gave the report of the committee appointed to consider the suggested ordinance. It was moved and seconded that the committee report be accepted and forwarded to headquarters office.

The meeting adjourned at 10:00 p. m.

St. Louis Chapter Meetings

March 7, 1939. St. Louis Chapter met at the David Ranken School, and dinner preceding the meeting was served to 55. Later there were approximately 160 present to hear Dr. Charles Sheard, the speaker of the evening.

Pres. E. E. Carlson called the meeting to order and welcomed all of the members and guests. He then called for three members from the floor to act on the Nominating Committee and the following were named: Paul Sodemann, J. H. Carter and G. W. F. Myers. President Carlson appointed J. M. Foster and R. C. Driemeyer to complete the Nominating Committee and Mr. Myers to act as chairman. This committee will make their report at the April meeting.

President Carlson declared a brief recess and R. J. Tenkonohy,

chairman of the Program Committee, then introduced Dr. Sheard, director of Biophysical Research, Mayo Foundation, Rochester, Minn. Dr. Sheard delivered a very interesting paper on the subject, Thermal Interchange Between the Body and Its Environment.

The meeting adjourned at 9:45 p.m. according to the report of Secy D. J. Fagin.

February 7, 1939. Pres. E. E. Carlson called the St. Louis Chapter meeting to order at the Kingsway Hotel, following dinner which was served to 30.

After welcoming those present, President Carlson announced that a dinner dance was planned for March 9 at the Coronado Hotel in honor of the War Department Ordnance Division.

President Carlson then spoke on the high lights of the Society's Annual Meeting in Pittsburgh, which approximately 10 St. Louisians attended.

The meeting was turned over to R. J. Tenkonohy, chairman of the Program Committee, who introduced W. P. Norris. Mr. Norris led a discussion on a recently published paper, entitled Frictional Resistance to the Flow of Air in Straight Ducts.

After a brief recess, Mr. Tenkonohy introduced Charles Barclay, Ralston-Purina Co., St. Louis, who spoke on the subject of Air Conditioning of Offices Using Centrifugal Refrigeration. Mr. Barclay's talk was well received, as evidenced by the number of questions and the discussion which followed.

January 10, 1939. At this meeting at the Kingsway Hotel dinner was served to 47 and approximately 35 additional members and guests were present at the business session.

After calling the meeting to order, Pres. E. E. Carlson turned the gavel over to R. J. Tenkonohy, chairman of the Program Committee, who introduced S. R. Lewis, consulting engineer, Chicago. Mr. Lewis presented a very interesting paper on the subject of A Heating and Air Conditioning Man Discusses His Troubles.

Pres. J. F. McIntire Visits Western New York Chapter

March 13, 1939. Western New York Chapter met at the University Club, Buffalo, with 44 members and guests attending. Minutes of the February meeting were read and approved.

S. W. Strouse announced for the Program Committee that at the April meeting the Chapter would be guests of the Iroquois Gas Co.

C. W. Farrar outlined in detail plans for the Semi-Annual Meeting of the Society at Mackinac Island and announced the dates of July 4-6 and the cost of the trip from Buffalo.

The Chapter voted unanimously to register its opposition to that section of the amendment to the City Ordinance for requirements of stationary and hoisting engineers which proposed that only certain steam heating systems below 10 lb pressure be exempt from requiring a licensed engineer. Secy. W. R. Heath was instructed to prepare a letter to the Common Council stating this opposition, and Walter Davis requested that it be presented at the Council meeting March 14, 1939.

Pres. J. J. Landers then turned the meeting over to L. A. Harding, who acted as toastmaster and introduced W. A. Russell, Waterbury, Conn., member of the Council of the ASHVE, who presented his greetings to the chapter. Mr. Harding then presented J. F. McIntire, Detroit, president of the ASHVE, who discussed The Birth of Air Conditioning and Its Future. Mr. McIntire outlined the activities of the Society, especially emphasizing the research work. He then traced the air conditioning industry from the time of Benjamin Franklin and mentioned the antiquity of many present day air conditioning devices.

February 13, 1939. Fifty-one members and guests attended the Western New York Chapter meeting at the University Club, Buffalo. Minutes of the January meeting were read and approved.

Pres. J. J. Landers read a letter from the Buffalo Chapter of the *American Institute of Architects* requesting the ASHVE Chapter's cooperation in opposing the Phelps and Dollinger Bills. This was referred to the Board of Governors for action.

President Landers and M. C. Beman reported on the business transacted at the Society's Annual Meeting in Pittsburgh and told of preliminary plans for the Semi-Annual Meeting at Mackinac Island.

L. P. Saunders, chairman of the Membership Committee, outlined the advantages of Society membership and introduced five guests from Rochester.

C. A. Gifford announced that J. F. McIntire, president of the ASHVE, would be the speaker in March.

The first speaker of the meeting was E. T. Hayes, Fox Furnace Division of American Radiator Corp., who traced the history of warm air heating from the days of the "hot-air" furnace to present air conditioning systems.

The second speaker was W. T. Kaiser, American Gas Products Division, who outlined the advantages of vapor and steam heating systems, and the third speaker was H. C. Day, manager, Buffalo division, American Radiator Corp., who told his reasons for preferring hot water heating systems.

According to Secy. W. R. Heath's report, many of the members joined in a discussion of the various systems after the speakers had concluded.

THREE VIEWS

I quote from three letters received during the past month illustrating three different attitudes toward membership.

No. 1. **"At the present time we have four applications, and our committee, of which there are seven members besides myself, is very active."**

No. 2. **"We rather feel that our membership job is to act as a sort of information bureau to those who express interest and, until they do, our general policy has been not to do anything."**

No. 3. **"We have not yet appointed a membership chairman. It is my intention to have every chapter member contact those whom he thinks would make good material, but it is not our intention to see how many engineers we can get to sign membership blanks."**

The first letter is from the chairman of the Membership Committee of one of the largest Chapters in proportion to the population that there is in the Society. I think the reason is obvious.

The usefulness of any organization is limited by the number of people it reaches.

E. K. Campbell, *Chairman*
Membership Committee, ASHVE

Four D's of Air Conditioning Discussed at Illinois Meeting

February 13, 1939. The regular meeting of Illinois Chapter was called to order at 7:45 p.m. with 88 members and guests in attendance. I. E. Brooke, chairman of the Membership Committee, introduced S. H. Merens, a new member. At the suggestion of Pres. J. R. Vernon it was voted that minutes of the past meeting and regular reports of committees be dispensed with due to the length of the program.

Secy. M. W. Bishop read the report of the Annual Meeting of the Society in Pittsburgh and J. J. Aeberly reported on Council activities. The Secretary read an announcement of the Conference on Air Conditioning at the University of Illinois.

R. E. Hattis brought up the matter of the proposed Illinois Chapter membership in the Illinois Engineering Council, and at his request the Secretary read Mr. Aeberly's report of the Council on this matter. After some general discussion, H. G. Chapin moved that the Board of Governors make a study of Illinois Engineering Council and submit a written factual re-

port without recommendation to the membership. The motion was seconded and carried.

Tom Brown then introduced W. G. Boales, Detroit, who described the coming Semi-Annual Meeting at Mackinac Island. E. J. Goebel and James Thompson of the Georgian Bay Line described and illustrated some of the activities and entertainments to be anticipated on the cruise.

President Vernon introduced the speaker of the evening, J. H. Van Alsburg, of the Society's Speakers Bureau whose subject was The Four D's of Air Conditioning. Mr. Van Alsburg introduced his remarks by pointing out that an air conditioning system may be very carefully designed, with due consideration given to the requirements and the best obtainable equipment used for the installation, all properly sized, yet the installation may still result in unsatisfactory results if careful consideration is not given to the four "D's" of air conditioning—ducts, dampers, distribution and deflection. These four factors are most important because, according to the speaker, they are varied by building limitations and, allowing for human errors, are seldom installed exactly as originally laid out.

The fact that the ASHVE appreciates the importance of these four factors is indicated by the great amount of research being done either independently or in cooperation with others on these four items. The speaker brought out that during 1938 the Society's research budget was approximately $30,000 and in addition, because of cooperative projects, with matched expenditures by the various institutions concerned, an amount in excess of $100,000 was spent for research.

The first paper on duct friction based on three years' intensive work at the ASHVE Research Laboratory in Pittsburgh was recently published. This work on straight ducts with both round and square cross-sections substantiates previous work, points out errors in the past, and gives new factors for friction in ducts of varying materials and different spacing of joints.

Using blackboard illustrations, Mr. Van Alsburg described some of the results of this research work, together with that done at the University of Illinois with examples of frictional resistance of elbows of varying radii and design and losses resulting from converging or diverging streams of air.

The importance of even distribution to obtain even air motion in the space was brought out and the necessity of equal rather than average face velocity across supply openings was emphasized. Turning blades in approaches immediately back of supply openings where turns exist are frequently necessary to obtain these results; this being especially true where it is desired to discharge air at a specified velocity in order to reach the opposite wall at a certain terminal velocity.

The question of distribution is tied up closely with the fourth "D," deflection, which is merely another word for *grille*, according to the speaker. For many years, manufacturers attempted to make grilles, giving consideration to appearance only and in so doing often produced a grille whose purpose of admitting or passing air was severely hindered. Today, however, grilles are manufactured to fill a definite need in controlling the discharge of air to give a desired result. Work is being carried on at the University of Illinois in a cubical room within a room to determine what supply opening location or locations and what exhaust opening locations give the most even room temperature and the most equal air motion under varying conditions of exposure.

The speaker devoted the balance of his remarks to descriptions of the research work being carried on at Case School of Applied Science on the testing of air measuring instruments; at the University of Wisconsin to determine the best method of approach to grilles for equal face velocity; and at Lehigh University on the effect of turning blades on elbows. In the Society's Research Laboratory work will be carried on this year on frictional resistance in rectangular ducts of various dimensional ratios and various elbows and fittings.

A general discussion followed in which Messrs. Aeberly, Hattis, Chapin, Brown, F. I. Raymond, and Dr. Carter of the *American Medical Association* took part.

G. L. Larson Addresses Cleveland Members

March 13, 1939. Northern Ohio Chapter met at the Cleveland Club with 25 present for dinner and 63 at the meeting which followed. Pres. J. P. Jones presided and the minutes of the preceding meeting were read by Secy. C. M. H. Kaercher and approved.

A letter was then read by Secretary Kaercher from one of the Chapter members, R. A. Wilson, expressing appreciation for a floral offering sent on the occasion of his wife's death.

Mr. Atchinson of the *Cleveland Society of Professional Engineers* extended an invitation to the ASHVE members to attend an inspection trip through the Iron Fireman factory on April 3.

President Jones then called for reports of standing committees and C. F. Eveleth of the Publications Committee gave a very complete review of recent articles of interest in the trade magazines.

A communication was read from the *Cleveland Engineering Society* asking for comment on a suggested draft of a Code for Air Conditioning to be incorporated as part of the Cleveland city building code. A code was suggested following along the lines of one drafted by the *American Society of Refrigerating Engineers* and concerning itself chiefly with safety standards.

President Jones turned this matter over to the Standards Committee and appointed L. T. Avery and H. E. Wetzell as additional temporary members of the committee so as to have the benefit of their knowledge.

D. L. Taze as chairman of the Membership Committee presented the applications of R. J. Harrison, Fred Maurer and C. F. Cushing. It was moved and seconded that these three candidates be accepted into the Northern Ohio Chapter.

Secretary Kaercher, who was a delegate to the Society's Annual Meeting in Pittsburgh, read a written report of the proceedings of the Chapter Delegates' Conference. Mr. Avery commented on the fact that the Chapter had 27 representatives at the Pittsburgh meeting, seven of whom were accompanied by their wives.

The attention of the members was called to the Semi-Annual Meeting of the ASHVE at Mackinac Island, July 4-6, and Mr. Avery gave details as to approximate cost and the program to be followed.

The meeting was then turned over to the Program Committee, who introduced Prof. G. L. Larson, Madison, Wis., as the guest speaker. Professor Larson, who is a Past President of the Society, gave a talk on Hot Water Heating which was illustrated by slides. Upon conclusion of the talk the members expressed their appreciation by a rising vote of thanks to Professor Larson.

Society and Chapter Activities Discussed at Atlanta

March 7, 1939. The regular meeting of Atlanta Chapter was called to order by Pres. C. L. Templin at 8:00 p.m. at the Biltmore Hotel. Roll call was handled through the use of new buttons and recognition cards with 24 members and guests present. The minutes of the previous meeting were read and approved and reports of officers and committees were given.

The treasurer reported that a list of receipts and disbursements since the last meeting indicated that the members were cooperating with the Finance Committee in paying up their 1939 dues.

Secy. T. T. Tucker was advised to make a request to the Publicity Committee that in the future all three Atlanta papers carry notices of Chapter meetings.

It was decided that a special meeting should be held on March 20 in honor of J. F. McIntire, Detroit, president of the ASHVE, who will address Atlanta members and guests on The Birth of Air Conditioning and Its Future.

The gavel was then turned over to the Entertainment Commit-

tee, Vice-chairman F. L. Laseter presiding. The program opened with a talk by C. T. Baker on Our Part in the Society's Activities. This was followed by a question and answer period covering several specific actions taken by the Chapter. Secretary Tucker talked briefly on Our Progress in the Atlanta Chapter. More questions and answers followed as well as a discussion of social gatherings for the summer. President Templin was asked to investigate the possibility of a joint meeting with other engineering societies similar to that held last year.

There being no further business, the meeting adjourned.

Atlanta Chapter Host to J. F. McIntire

March 20, 1939. A special meeting of Atlanta Chapter was called to order at 8:00 p.m. at the Biltmore Hotel, with Vice-Pres. S. W. Boyd presiding. Roll call revealed 14 members and 18 visitors present.

Secy. T. T. Tucker introduced the speaker of the evening, who was J. F. McIntire, Detroit, Mich., president of the ASHVE. Mr. McIntire delivered a very interesting and entertaining talk on The Birth of Air Conditioning and Its Future, following which the meeting was open for discussion. During this part of the program President McIntire and Atlanta members discussed many interesting points which included the possibility of regional meetings, activity of the Chapter's Codes Committee, association with other engineering societies, securing new members and interesting other people in Chapter and Society activities.

Canadian Member Gets Pilot License

P. N. Foster, second vice-president of the *Manitoba Association of Sanitary and Heating Engineers*, has passed his final tests in flying and is now a full-fledged pilot, entitled to wear the coveted golden wings. Mr. Foster's home base is Flin Flon, Man.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 36 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge the members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by May 15, 1939, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
ADEMA, G. E., Htg. Contractor, N. M. Adema & Son, Buffalo, N. Y.	W. S. Eisele Joseph Davis	W. R. Heath Roswell Farnham
ANDERSON, E. J., Mfrs. Agent, Detroit, Mich.	W. G. Boales M. H. Goss	W. J. Whelan E. D. Sheley
BIERINGER, F. A., Asst. Chief Housheating Engr., Brooklyn Borough Gas Co., Brooklyn, N. Y.	M. C. Giannini P. B. Gordon	J. E. Godsoe (*Non-Member*) P. B. R. Baas (*Non-Member*)
BUCKLEY, D. J., Student, University of Illinois, Urbana, Ill.	W. H. Severns P. E. Mohn (*ASME*)	O. A. Leutwiler (*ASME*) H. J. Macintire (*ASRE*)
COOLEY, JOHN, Metropolitan Sales Mgr., Reynolds Metals Co., New York, N. Y.	Henry Gitterman W. E. Heibel	E. E. Adams W. T. Wrightson
COX, S. F., Dir. of Tech. Sales, Pittsburgh Corning Corp., Pittsburgh, Pa.	R. A. Miller, Jr. M. L. Carr	Leighton Orr F. C. Houghten
GOLDSMITH, ELLIOT, Design Engr., Anemostat Corp. of America, New York, N. Y.	F. J. Kurth Herbert Kunen	Fritz Honerkamp V. F. Self (*Non-Member*)
GOMINIAK, W. J., Student, Refrigeration & Air Cond. Inst., Chicago, Ill.	L. P. Saunders A. P. Griscom (*Non-Member*)	C. E. Knowles (*Non-Member*) S. A. Neilson (*Non-Member*)
HACH, E. C., Chief Engr., Sales Dept., Standard Air Cond., Inc., New York, N. Y.	J. I. Lyle V. S. Day	W. H. Baker, Jr. M. C. Terry
HANTHORN, WALTER, Engr., Kleenair Furnace Co., Portland, Ore.	J. D. Kroeker B. W. Farnes	T. E. Taylor E. C. Willey
HILL, EDWARD, JR., Htg. Engr., Fox Furnace Div., American Radiator Co., San Francisco, Calif.	C. L. Peterson C. E. Bentley	G. M. Simonson James Gayner
HYDE, E. V., Sales Promotion, Wood Conversion Co., St. Paul, Minn.	R. E. Backstrom F. B. Rowley	A. B. Algren D. B. Anderson
JOLLEY, E. M., Sales Dept., The Marley Co., Kansas City, Kan.	E. K. Campbell J. E. Matthews	Gustav Nottberg Carl Clegg
KEANE, G. F., In charge of Engrg., Cooney Refrigeration Co., Syracuse, N. Y.	A. R. Acheson E. C. Evans	N. E. Sheldon L. L. Lewis
KOLLAS, W. J., Chief Engr., Montag Stove & Furnace Works, Portland, Ore.	J. D. Kroeker E. C. Willey	J. A. Freeman B. W. Farnes